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Vascular Access

Clinical Practice Guidelines

of the European Society for Vascular Surgery

Writing Group Members

Jürg Schmidli (Chair)^a, Matthias K. Widmer (Co-Chair)^a, Carlo Basile^b, Gianmarco De Donato^c, Maurizio Gallieni^d, Christopher P. Gibbons^e, Patrick Haage^f, George Hamilton^g, Ulf Hedin^h, Lars Kamper^f, Miltos K. Lazaridesⁱ, Ben Lindsey^j, Gaspar Mestres^k, Marisa Pegoraro^l, Joy Roy^h, Carlo Setacci^c, David Shemesh^m, Jan H.M. Tordoirⁿ, Magda van Loon^o

Affiliations

^a Vascular Surgeon, Inselspital, Bern University Hospital, University of Bern, Switzerland

^b Nephrologist, Miulli General Hospital, Italy

^c Vascular Surgeon, University of Siena, Italy

^d Nephrologist, Nephrology and Dialysis Unit, Ospedale San Carlo Borromeo, University of Milano, Italy

^e Vascular Surgeon, Banbury Oxfordshire, UK

^f Radiologist, HELIOS Klinikum Wuppertal, University Hospital Witten/Herdecke, Germany

^g Vascular Surgeon, Royal Free London NHS Foundation Trust, London, UK

^h Vascular Surgeon, Karolinska University Hospital, Stockholm, Sweden

ⁱ Vascular Surgeon, Democritus University Hospital Alexandroupolis, Greece

^j Transplant Surgeon, Royal Free London NHS Foundation Trust, London, UK

^k Vascular Surgeon, Clinic Hospital. University of Barcelona, Spain

^l Clinical Nurse, Ospedale Niguarda, Milano, Italy

^m Vascular Surgeon, Shaare Zedek Medical Center, Jerusalem, Israel

ⁿ Vascular Surgeon, Maastricht University Medical Center, The Netherlands

^o Clinical Nurse, Maastricht University Medical Center, The Netherlands

Corresponding author

Jürg Schmidli, MD

Bern University Hospital

University of Bern

Freiburgstrasse, 3010 Bern, Switzerland

jurg.schmidli@insel.ch

Tel: +41 31 632 2602

Fax: +41 31 632 2919

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Table of contents

Abbreviations and acronyms

Chapter I Introduction

- 1.1. Purpose
- 1.2. Methodology

- 1.3. Definitions
 - 1.3.1. Definition of vascular access

 - 1.3.2. Other definitions

Chapter II Epidemiology of chronic kidney disease stage 5

- 2.1. Epidemiology of chronic kidney disease
 - 2.1.1. Epidemiology of end stage renal disease
 - 2.1.1.1. Incidence
 - 2.1.1.2. Prevalence
- 2.2. Demographics of end stage renal disease
- 2.3. Epidemiology of vascular access for dialysis

Chapter III Clinical decision making

- 3.1. Choice of vascular access
- 3.2. Timing of referral for vascular access surgery
- 3.3. Selection of modality of vascular access
 - 3.3.1. Primary option for vascular access – autogenous arteriovenous fistula
 - 3.3.1.1. Patient variables and outcome of vascular access
 - 3.3.2. Secondary option for vascular access
 - 3.3.3. Lower extremity vascular access
 - 3.3.4. Indications for a permanent catheter for vascular access

Chapter IV Preoperative imaging

- 4.1. Preoperative assessment
- 4.2. Imaging methods for vascular access surveillance and maintenance
 - 4.2.1. Duplex ultrasound
 - 4.2.2. Computed tomography
 - 4.2.3. Magnetic resonance imaging (MRI)
 - 4.2.4. Digital subtraction angiography (DSA)

Chapter V Creation of vascular access

- 5.1. Technical aspects
 - 5.1.1. Venous preservation

- 5.1.2. Arm exercises
- 5.1.3. Preoperative or perioperative hydration
- 5.1.4. Prophylactic antibiotics
- 5.1.5. Preoperative antiplatelet agents
- 5.1.6. Preoperative physical examination
- 5.1.7. Anesthesia
- 5.1.8. Microsurgery and tourniquet use
- 5.1.9. Perioperative anticoagulation
- 5.1.10. Arteriovenous fistula configuration
- 5.1.11. Surgical techniques
- 5.1.12. Choice of graft
- 5.1.13. Sutures or nitinol anastomotic clips
- 5.1.14. Other challenges
- 5.2. Perioperative assessment
- 5.3. Perioperative complications
 - 5.3.1. Hemorrhage
 - 5.3.2. Postoperative infection
 - 5.3.3. Non-infected fluid collections
 - 5.3.4. Early onset of vascular access induced limb ischemia
 - 5.3.5. Early thrombosis
- 5.4. Postoperative care
- 5.5. Training of surgeons to perform vascular access

Chapter VI Surveillance of vascular access

- 6.1. Access maturation and care
 - 6.1.1. Concept
 - 6.1.2. Maturation of arteriovenous fistula
 - 6.1.2.1. Physical assessment and other diagnostic methods
 - 6.1.2.2. Time to maturation
 - 6.1.3. Time to cannulation of the arteriovenous graft
 - 6.1.4. Access care
 - 6.1.5. Assessment and treatment of maturation failure
- 6.2. Measures to improve maturation
 - 6.2.1. Exercise
 - 6.2.2. Antiplatelets and anticoagulation
 - 6.2.3. Other treatment options
- 6.3. Cannulation
 - 6.3.1. Access care before cannulation
 - 6.3.1.1. Skin preparation
 - 6.3.1.2. Anesthesia
 - 6.3.1.3. Precannulation examination
 - 6.3.2. Cannulation techniques
 - 6.3.2.1. Needle selection
 - 6.3.2.2. Ultrasound-assisted cannulation
 - 6.3.2.3. Rope-ladder technique
 - 6.3.2.4. Area technique
 - 6.3.2.5. Buttonhole technique
 - 6.3.3. Access care after needle withdrawal
- 6.4. Access monitoring and surveillance

- 6.4.1. Concept
- 6.4.2. Monitoring
 - 6.4.2.1. Physical examination
- 6.4.3. Surveillance
 - 6.4.3.1. Surveillance during hemodialysis
 - 6.4.3.1.1. Flow measurements methods
 - 6.4.3.1.1.1. Indirect flow measurement
 - 6.4.3.1.1.2. Direct flow measurement
 - 6.4.3.1.2. Access flow and pressure surveillance
 - 6.4.3.1.3. Dialysis efficiency measurements
 - 6.4.3.1.3.1. Recirculation
 - 6.4.3.1.3.2. Urea Reduction Ratio (URR) and dialysis rate (Kt/V)
 - 6.4.3.2. Surveillance outside dialysis sessions
 - 6.4.3.2.1. Ultrasound
 - 6.4.3.2.2. Angiography
 - 6.4.3.2.3. MRA (CE-MRA, and NCE-MRA)
- 6.5. Nursing organization
 - 6.5.1. Introduction
 - 6.5.2. Nursing organization
 - 6.5.2.1. Nursing models
 - 6.5.2.2. Clinical governance
 - 6.5.2.3. Vascular access nurse
 - 6.5.2.3.1. Basic role
 - 6.5.2.3.2. Vascular access nurse coordinator and manager
 - 6.5.2.4. Future developments

Chapter VII Late vascular access complications

- 7.1. True and false access aneurysms
- 7.2. Infection
- 7.3. Stenosis and recurrent stenosis
 - 7.3.1. Inflow arterial stenosis
 - 7.3.2. Juxta-anastomotic stenosis
 - 7.3.3. Venous outflow stenosis
 - 7.3.4. Cephalic arch stenosis
- 7.4. Thrombosis
 - 7.4.1. Treatment of AVF thrombosis
 - 7.4.2. Treatment of AVG thrombosis
- 7.5. Central venous occlusive disease
 - 7.5.1. Hemodialysis-associated venous thoracic outlet syndrome
- 7.6. Vascular access induced limb ischemia and high-flow vascular access
- 7.7. Neuropathy
- 7.8. Non-used vascular access

Chapter VIII Complex or tertiary hemodialysis access

- 8.1. Tertiary vascular access
 - 8.1.1. Suggested classification of types of tertiary vascular access surgery.

- 8.1.1.1. Group one – Upper limb, chest wall and trans-located autologous vein from the lower limb
 - 8.1.1.1.1. Great saphenous vein and femoral vein translocation
 - 8.1.1.1.2. Access to the right atrium
- 8.1.1.2. Group two - lower limb
 - 8.1.1.2.1. Great saphenous vein
- 8.1.1.3. Group three – Access spanning the diaphragm, other exotic access and prosthetic upper or lower limb arterio-arterial loops.
 - 8.1.1.3.1. Axillo-iliac, axillofemoral and axillopopliteal
 - 8.1.1.3.2. Arterial – arterial chest wall and lower limb loops
- 8.2. Complex central venous catheters

Chapter IX GAPS in the Evidence

References

Appendix I: RECOMMENDED ADDITIONAL REFERENCES

Abbreviations and acronyms

Abbreviations	Term	Synonym
ABI	Ankle brachial index	
AVA	Arteriovenous access	
AVF	Arteriovenous fistula	Autogenous or native fistula
AVG	Arteriovenous graft	Prosthetic graft
BBAVF	Brachio-basilic AVF	
BBRAVF	Brachio-brachial AVF	
BCAVF	Brachio-cephalic AVF	
BFR	Blood flow rate	
BVT	Basilic vein transposition	
CAPD	Continuous ambulatory peritoneal dialysis	
CCPD	Continuous cyclic peritoneal dialysis	
CE-MRA	Contrast enhanced magnetic resonance angiography	
CFD	Complication-free days	
CHF	Congestive heart failure	
CKD	Chronic kidney disease	
CLS	Catheter lock solution	
CO	Cardiac output	
CPR	Cardiopulmonary recirculation	
CTA	Computed tomography angiography	
CVC	Central venous catheter	
CVD	Cardiovascular disease	
CVOD	Central venous occlusive disease	
DBI	Digital-brachial index	
DOPPS	Dialysis outcomes and practice patterns study	
DEB	Drug eluting balloon	
DRAL	Distal radial artery ligation	
DRIL	Distal revascularization and interval ligation	
DSA	Digital subtraction angiography	
DUS	Duplex ultrasonography	
ePTFE	expanded polytetrafluoroethylene	
ESRD	End-stage renal disease	

ESVS	European Society for Vascular Surgery	
GFR	Glomerular filtration rate	
GSV	Great saphenous vein	
HD	Hemodialysis	
HD catheter	Catheter of any kind used for hemodialysis	
HeRO	Hemodialysis reliable outflow device	
IMN	Ischemic monomelic neuropathy	
IPD	Intermittent peritoneal dialysis	
KDOQI	Kidney diseases outcome quality initiative	
LEAVG	Lower extremity AVG	
MAP	Mean arterial pressure	
MIH	Myointimal hyperplasia	
MRA	Magnetic resonance angiography	
MRI	Magnetic resonance imaging	
NCE-MRA	Non contrast enhanced magnetic resonance angiography	
NKF-KDOQI	National Kidney Foundation for Kidney diseases outcome quality initiative	
NSF	Nephrogenic systemic fibrosis	
ntCVC	Non tunneled central venous catheter	indwelling catheter without cuff
PAI	Proximalisation of arterial inflow	
PAD	Peripheral arterial disease	
PAVA	Proximalisation of the arteriovenous anastomosis	
PD	Peritoneal dialysis	
PICC	Peripherally inserted central venous catheter	
PNV	Pre-nephrology visit	
PP	Primary patency	
PRAL	Proximal radial artery ligation	
PRCAVF	Posterior radial branch cephalic AVF	snuff box fistula
PTA	Percutaneous transluminal angioplasty	balloon angioplasty
PU	Polyurethane	
Qa	Access blood flow	
Qb	Blood pump flow delivered to the dialyzer	
RCAVF	Radio-cephalic AVF	Cimino-Brescia fistula

RCT	Randomized controlled trial	
RRT	Renal replacement therapy	
RUDI	Revision using distal inflow	
SFA	Superficial femoral artery	
FV	Femoral vein (former superficial femoral vein)	
FVT	Femoral vein transposition	
SP	Secondary patency	
SSV	Small saphenous vein	
tcCVC	Tunneled cuffed central venous catheter	indwelling catheter with cuff
UCAVF	Ulna-cephalic AVF	
UDT	Ultrasound dilution technique	
URR	Urea reduction ratio	
VA	Vascular access	
VAILI	Vascular access induced limb ischemia	
VAS	Vascular Access Society	
VP	Venous pressure	
VP/MAP	Venous pressure adjusted for the mean arterial pressure	
WC	Writing committee	

Chapter I

Introduction

1.1. Purpose

The European Society for Vascular Surgery (ESVS), according to its mission, appointed the Vascular Access (VA) Writing Committee (WC) to write the current clinical practice guidelines document for surgeons and physicians who are involved in the care of patients with HD and VA. The goal of these Guidelines is to summarize and evaluate all the current available evidence to assist physicians in selecting the best management strategies for all patients needing a VA or for pathologies derived by VA. However, each respective physician must make the ultimate decision regarding the particular care of an individual patient.(1, 2) Patients with VA for HD are complex and are subject to significant clinical practice variability, although a valid evidence base is available to guide recommendations. The significant technical and medical advances in VA have enabled guidelines to be proposed with greater supporting evidence than previously. Potential increases in health care costs and risks due to the industry- and public-driven use of novel treatment options makes the current guidelines increasingly important. (3-6)

Many clinical situations involving patients with HD and VA have not been subjected to randomised clinical trials. Nevertheless, patient care must be delivered and clinical decisions made in these situations. Therefore, this document should also provide guidance, when extensive level I evidence is unavailable and, in these situations, recommendations are determined on the basis of the best currently available evidence.

By providing information on the relevance and validity of the quality of evidence, the reader will be able to gather the most important and evidence-based information relevant to the individual patient.

This document is intended to be a guide, rather than a document of rules, allowing flexibility for specific patients' circumstances. The resulting clinical practice guidelines document

provides recommendations for the clinical care of patients with HD and VA including preoperative, perioperative and postoperative care and long-term maintenance.

1.2. Methodology

The VA WC was formed by members of ESVS and VAS (Vascular Access Society) from different European countries, various academic and private hospitals and by vascular surgeons, nephrologists, radiologists and clinical nurses in order to maximize the applicability of the final guideline document. The VA Guideline WC met in September 2012 for the first time to discuss the purpose, contents, methodology and timeline of the following recommendations.

The VA WC has performed a systematic literature search in MEDLINE, EMBASE and COCHRANE Library databases for each of the different topics that are discussed and reviewed in this guidelines document. The latest literature search was performed in November 2015. With regard to evidence gathered, the following eligibility criteria have been applied:

- Only peer-reviewed published literature has been considered
- Published abstracts or congress proceedings have been excluded
- Randomized clinical trials (RCT) as well as meta-analyses and systematic reviews were searched with priority
- Non-randomized clinical trials and non-controlled trials were included
- Well-conducted observational studies (cohort and case-control studies) were also included
- Previous guidelines, position papers and published consensus documents have also been included as part of the review process when new evidence was absent
- Minimizing the use of reports from a single medical device or from pharmaceutical companies reduced risk of bias across studies.

A grading system based on the European Society of Cardiology (ESC) guidelines methodology was adopted.(7) The level of evidence classification provides information about the study characteristics supporting the recommendation and expert consensus, according to the categories shown in Table 1.

Table 1 : Levels of evidence (7)

Level of Evidence A	Data derived from multiple randomized clinical trials or meta-analyses.
Level of Evidence B	Data derived from a single randomized clinical trial or large non-randomized studies.
Level of Evidence C	Consensus of opinion of the experts and/or small studies, retrospective studies, registries.

The recommendation grade indicates the strength of a recommendation. Definitions of the classes of recommendation are shown in Table 2.

Table 2 : Grades of strength of recommendations according the ESC grading system
(7)

Classes of Recommendation	Definition
Class I	Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective. <i>It should be performed.</i>
Class II	Conflicting evidence and /or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.
Class IIa	Weight of evidence/opinion is in favour of usefulness/efficacy. <i>It should be considered.</i>
Class IIb	Usefulness/efficacy is less well established by evidence/opinion. <i>It may be considered.</i>
Class III	Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful. <i>It is not recommended.</i>

For each recommendation, two members of the WC assessed the strength of a recommendation and the quality of supporting evidence independently. A full master copy of the manuscript with all recommendations was electronically circulated and approved by all WC members. Recommendations that required consensus were discussed and voted upon meetings and by e-mailing among all members of the WC. This system permits strong recommendations supported by low or very low-quality evidence from downgraded RCTs or observational studies only when a general

consensus among the WC members and reviewers is achieved.

Two members of the WC have prepared each part of the guidelines document. An internal review process was performed before the manuscript was sent to independent external reviewers. External reviewers made critical suggestions, comments and corrections on all preliminary versions of this guideline. In addition, each member participated in the consensus process concerning conflicting recommendations. The final document has been approved by the ESVS Guidelines Committee and submitted to the European Journal of Vascular and Endovascular Surgery (EJVES). Further updated guidelines documents on VA will be provided periodically by the ESVS when new evidence and/or new clinical practice arise in this field, which could occur every four years. To optimize the implementation of the current document, the length of the guidelines has been kept as short as possible to facilitate access to guideline information. This clinical guidelines document was constructed as a guide, not a document of rules, allowing for flexibility with various patient presentations. The resulting clinical practice guidelines provide recommendations for the clinical care of patients with VA including preoperative, perioperative and post-operative care.

Conflicts of interest from each WC member were collected prior to the writing process. These conflicts were assessed and accepted by each member of the WC and are reported in this document. In addition, the WC agreed that all intellectual work should be expressed without any interference beyond the honesty and professionalism of all members and assistants during the writing process.

1.3. Definitions

1.3.1. Definition of vascular access

Patients with acute renal failure or end stage renal disease require renal replacement therapy by peritoneal dialysis (PD), hemodialysis (HD) or kidney transplantation (Figure 1). VA is essential for patients on HD and can be accomplished either using central venous

catheters (CVC), or by arterialization of a vein or interposing of graft between an artery and a vein for the insertion of HD needles. The blood flow available for HD should reach at least 300ml/min and preferably to 500ml/min depending on the access modality to allow a sufficient HD.

Treatment options for patients with ESRD

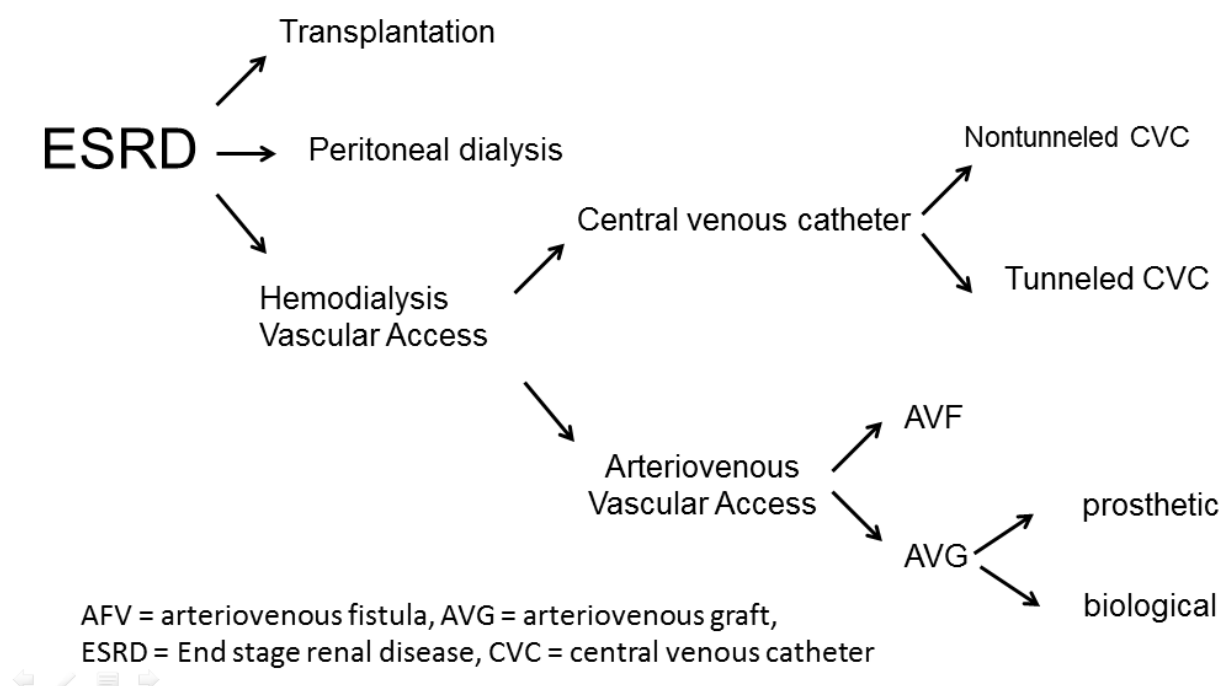


Fig. 1 Renal replacement therapy

1.3.2. Other definitions

Arteriovenous fistulas (AVF) and arteriovenous grafts (AVG) are established terms to characterize a special kind of VA in patients on HD. We define an autogenous anastomosis between an artery and a vein as an **arteriovenous fistula** and an access using a prosthetic graft as **arteriovenous grafts**.

At the beginning of this millennium interventional radiologists and vascular surgeons attempted to clarify the terminology dealing with HD access.(8-10) Some of these definitions have been revised and (11) further refinements made; there is still ongoing discussion amongst VA specialists. Nevertheless we have outlined below the definitions that we believe to be currently accepted by the majority of clinicians in the field.

Table 3: Classification of chronic kidney disease based on glomerular filtration rate (GFR) (8-11)

Stage	Description	GFR mL/ Min / 1.73 m²
Stage 1	Kidney damage with normal or elevated GFR	90+
Stage 2	Kidney damage with mildly decreased GFR	60-89
Stage 3	Moderately decreased GFR	30-59
Stage 4	Severely decreased GFR	15-29
Stage 5	End-stage kidney failure (ESRD)	< 15 or on dialysis

Incidence is the proportion of a given population developing a new condition or experiencing an event within a specified period of time. This could be i.e. the number of patients experiencing an event (e.g. patients undergoing vascular access creation) divided by the number of a given population (e.g. the number of patients undergoing HD). For a disease incidence can be expressed as number of patients per million population per year.

Prevalence is the total number of cases of a disease within a given population; it encompasses both new and continuing patients with a certain disease and is expressed as patients per million population. Prevalence is a function of incidence (new cases) and outcomes (death or cure).

Point prevalence in %: Number of patients using a specific type VA at a given point of time divided by the number of patients with a VA at this time multiplied by 100.

Period prevalence in %: The mean number of patients using a specific VA over a given time (one year) divided by all the number of patients using a VA during the same time period multiplied by 100.

Hospitalisation days/1000 access days: The numerator is the total number of days of hospitalization for the study population. The denominator is calculated as the number of days from access creation or the start date of a study period to permanent (unsalvageable) access failure, the end of study period, death of the patient, transfer from the dialysis unit or a change in modality of renal replacement (peritoneal dialysis or transplantation). The calculated rate is the total number of hospitalization days/total number of access days multiplied by 1000 to achieve the number of hospitalization days/1000 access days.

Access abandonment: The day on which an access is deemed to be permanently unusable or unavailable for cannulation.

Primary VA: Creation of a functioning VA for the first time. It can be reported using a standard time to event analysis (Kaplan-Meier) or specific time points (30 days, 6 month, one year/ two years).

Secondary VA: VA creation after a failed VA.

Tertiary VA: VA using GSV or FV translocated to the arm or leg. Unusual access procedures such as upper or lower limb arterio-arterial loops are included in this category

Transposition: Relocation of an autogenous vein to a new (more superficial) position in the soft tissues of the same anatomical area (e.g. an upper arm AVF with transposition of the basilic vein).

Translocation: The prepared vein is completely disconnected and inserted in a new anatomical area to create an AVF.

Superficialization: the index vein is elevated in the subcutaneous tissue without any detaching or rerouting the vein.

Kaplan-Meier life-table: A statistical method for calculating time-dependent clinical outcomes can be documented such as access patencies, time to thrombosis or infection free survival.

Primary patency: The interval between VA creation and the first re-intervention (intervention-free access survival) for access dysfunction or thrombosis or the time of measurement of patency

Assisted primary patency: Interval between VA creation and the first occlusion (thrombosis-free access survival) or measurement of patency including operative/endovascular interventions to maintain the VA.

Primary functional patency: Interval between the first use (first cannulation) of new created VA and the first re-intervention to rescue the VA.

Secondary patency: Interval between VA creation and the abandonment of this VA (i.e. thrombosis) after one or more interventions or achievement of a censored event (death, change of HD modality, loss for follow-up). This can be documented graphically as cumulative survival curve.

Maturation of VA: Changes that occur in the VA after its creation (increase in access flow and AVF diameter, wall structure changes, AVG tissue-to-graft incorporation) making the access to become over time suitable for cannulation.

Mature VA: A VA that is expected to be suitable for HD access and considered appropriate for cannulation with two needles and expected to deliver sufficient blood flow throughout the HD. Therefore it is a pre-cannulation definition.

Adequate VA: A VA is adequate, appropriate or suitable for HD when it has been cannulated successfully with two needles, over a period of at least 6 HD sessions during a 30-day period, and delivering the prescribed blood flow throughout the HD and achieves adequate HD (usually at least 300 ml/ min). Therefore it is a post-cannulation definition.

Functional VA: A VA that is currently being used for HD access.

Monitoring: Examination and evaluation of the VA by means of physical examination to detect physical signs that suggest the presence of access dysfunction

Surveillance: Periodic evaluation of a VA by using hemodynamic tests. This may trigger further diagnostic evaluation.

VA induced (limb) ischaemia: Upper extremity malperfusion after VA creation can be classified in four stages:

stage 1: slight coldness, numbness, pale skin, no pain

stage 2: loss of sensitivity, pain during HD or exercise

grade 3: rest pain

grade 4: digital tissue loss

The definition is more appropriate than 'steal' which describes the physiological phenomena of a (even retrograde) blood flow recruitment towards the AVF/AVG.

Recirculation: The return of dialyzed blood to the systemic circulation without full equilibration (NKF-DOQI guidelines)

Kt/V: A parameter to quantify the adequacy of the HD : K = Dialyzer clearance of urea, t = effective time of HD V = volume of urea distribution , approx. equal to patient's body water (60% of the body mass).

Early VA failure: A VA that has occluded within 24 hours of creation.

Early dialysis suitability failure: A VA that cannot be used by the third month following creation despite radiological or surgical intervention.

Late dialysis suitability failure: A VA that is not usable after more than 6 months despite radiological or surgical intervention.

Cannulation failure: Failure is defined as the inability to place and secure two dialysis needles.

Non-tunneled CVC: An uncuffed catheter providing temporary VA for HD.

Tunneled CVC: A subcutaneously tunneled dual-lumen catheter with a cuff that can be used for VA if HD is expected to last for more than two weeks.

Catheter related bacteremia:

Definite: Bacteremia with at least one positive percutaneous peripheral vein blood culture and where either the same pathogen was cultured from the catheter tip or a blood culture drawn from a catheter that has a > 3 fold greater bacterial colony count than those drawn from a peripheral vein.

Likely: Bacteremia with positive blood cultures obtained from a catheter and/or peripheral vein in a patient where there is no clinical evidence for an alternative source of an infection.

Catheter exit site infection:

Proven: The presence of a purulent discharge or erythema, induration/and or tenderness at catheter exit site with a positive bacteriological culture of serious discharge.

Probable: The clinical signs of infection with negative cultures from the discharge or blood without signs of irritation from gauze, stitches or the cleansing agent.

Catheter tunnel infection:

Proven: The presence of purulent discharge from tunnel or erythema, induration and/or tenderness over the catheter tunnel with a positive culture.

Probable: Clinical signs of infection around the catheter site with negative cultures from the discharge or blood.

Primary catheter site patency: Interval between catheter insertion and the first intervention to save the catheter's function.

Secondary catheter site patency: Interval between catheter insertion and exchange or removal of the catheter for any reason.

Continuous catheter site: The time period from initial catheter insertion to **catheter site** abandonment for any reason including the time period after continuous catheter exchanges

in the same target vessel. The time period and number of exchanges are documented e.g. 12 months [3 catheters].

Catheter dysfunction: This is the first occurrence of either a peak flow of 200 ml/minute or less for 30 minutes during HD, a mean blood flow of 250 ml/minute or less during two consecutive dialyses or the inability to initiate HD resulting from an inadequate blood flow, despite attempts to restore patency.

Chapter II

Epidemiology of chronic kidney disease (CKD) Stage 5

2.1. Epidemiology of chronic kidney disease

Chronic kidney disease (CKD) is a worldwide public health problem. CKD is defined as kidney damage or glomerular filtration rate (GFR) below 60 ml/min per 1.73 m² for 3 months or more irrespective of the cause. CKD is classified into five stages (Table 3).(12)

The true incidence and prevalence of CKD within a community are difficult to ascertain as early to moderate CKD is usually asymptomatic. Most studies point to a prevalence of CKD of around 10%, albuminuria of around 7%, and GFR below 60 ml/min per 1.73 m² of around 3%.(13-15)

CKD stage 5 (ESRD) is characterized by GFR below 15 ml/min per 1.73 m² and includes two phases: the first one is treated conservatively without dialysis; when the second phase follows, the initiation of renal replacement therapy (RRT) in the form of dialysis or transplantation is required to sustain life.

Incidence of CKD stage 5 refers to the number of patients with ESRD beginning RRT, thus failing to take into account patients not treated by RRT and underestimating the overall true

incidence of ESRD. In the dialysis population, prevalence is a function of the incidence (new cases) and outcome (transplantation or death) rates of ESRD.

2.1.1. Epidemiology of end stage renal disease

2.1.1.1. Incidence

The number of patients per year starting RRT has shown an exponential rise. (16) Such a large number of CKD patients requiring dialysis may have three main causes: patient selection, competitive risks and true increase in CKD incidence:

1. Selection of patients for RRT: the steep increase in the incidence of older patients suggests that those very old and/or those affected by particularly severe comorbidities did not get access to dialysis in the first decades of RRT, compared to the more recent years.

2. Competitive risks: a very recent study suggested that the number of deaths where CKD is the underlying cause of death increased by 82% from 1990 (27th in the global death rank) to 2010 (18th in the global death rank).(17) A high risk of death exists even in patients in the early stages of CKD, with many individuals in stages 3 and 4 dying before starting RRT.(18, 19) In fact, a reduced GFR is considered as one of the most important risk factors for coronary heart disease.(20) Substantial improvements in the treatment of cardiac diseases and in survival have occurred in the last decades and this has allowed many patients to survive in the more advanced CKD stages and to require RRT.

3. True increase in CKD incidence: it may also be possible that the increased incidence of ESRD reflects increases in the underlying prevalence of CKD. The Framingham Heart Study has shown that the incidence of type 2 diabetes has doubled from the 1970s to the 1990s.(21) Furthermore, potentially nephrotoxic drugs, such as non-steroidal anti-inflammatory drugs, antibiotics and chemotherapy agents are more commonly used.

2.1.1.2. Prevalence

Data related to the prevalence of CKD stage 5 are lacking, except for those of registries of ESRD patients treated by dialysis or transplantation. In the USA, of the 547,982 prevalent ESRD patients in 2008, 70 percent were being treated with dialysis while 30 percent had a functioning graft. In 2008 alone, 112,476 patients entered the US ESRD program. Adjusted rates for incident and prevalent ESRD are 351 and 1,699 cases per million population, respectively. Diabetes and hypertension account for 44 and 27.9 per cent of all causes of incident ESRD, respectively.(22)

The prevalence of a disease increases if the survival of the patient increases with a constant incidence rate or if the incidence rate increases with a constant survival rate. The rising prevalence of treated ESRD can be attributed to the increase in the number of patients who start RRT each year and/or to increased survival of patients with ESRD. Since the incidence rates of treated ESRD have flattened in recent years, longer lifespans of prevalent ESRD patients may partially explain the steady growth of this population.(22) Continuing global efforts should be made in the prevention and treatment of acute and especially chronic conditions potentially leading to ESRD, in particular diabetes and hypertension.

2.2. Demographics of end stage renal disease

The global epidemiology of ESRD is heterogeneous and influenced by several factors. Consequently, the incidence and prevalence of ESRD are markedly different from country to country (Table 4). Disparities in the incidence and prevalence of ESRD within and between developed countries reflect racial and ethnic diversities as well as their impact on the prevalence of diabetes and hypertension in respective countries and communities. The incidence is higher among African and Native Americans and aboriginals of Australia and New Zealand.(12, 22-26) Diabetes as cause of ESRD is particularly frequent in these populations. Disparities with developing countries are likely to reflect availability of and access to RRT in low and middle income economies rather than a lower incidence of CKD.

Diabetes as the primary cause of CKD affects a particularly high percentage of incident patients in the USA.

The elderly are a substantial and growing fraction of the RRT population worldwide, reaching 25-30% in most ESRD registries.(22, 24) In the United States, the proportion of patients > 65 years of age starting dialysis has increased by nearly 10% annually, representing an overall increase of 57% between 1996 and 2003.(22) In Canada, from 1990 until 2001, the incident dialysis rate among patients aged 75 and older increased 74%.(25) Researchers have speculated that more liberal acceptance of the very elderly (≥ 80 years) into dialysis programs has contributed to the increase in patients with ESRD(27, 28).

CKD is expected to be a major 21st century medical challenge. In developing nations, the growing prevalence of CKD has severe implications on health and economic output.(29) The rapid rise of common risk factors such as diabetes, hypertension and obesity, especially among the poor, will result in even greater and more profound burdens that developing nations are not equipped to handle.(29)

Table 4. Global incidence and prevalence of RRT (per million population) in different parts of the world in 2002 and 2006.

	Incidence		Prevalence	
	2002	2006	2002	2006
UNITED STATES	333	360	1,446	1,626
Caucasians	255	279	1,060	1,194
African Americans	982	1,010	4,467	5,004
Native Americans	514	489	2,569	2,691
Asians	344	388	1,571	1,831
Hispanics	481	481	1,991	1,991
AUSTRALIA	94	115	658	778

Aboriginals, Torres Strait	393	441	1,904	2,070
EUROPE	129	129	770	770
United Kingdom	101	113	626	725
France	123	140	898	957
Germany	174	140	918	957
Italy	142	133	864	1,010
Spain	126	132	950	991
JAPAN	262	275	1,726	1,956

Source: References 20-23

2.3. Epidemiology of vascular access for dialysis

Large differences in VA exist between Europe, Canada, and the United States, even after adjustment for patient characteristics.(30) VA care is characterized by similar issues, but with a different magnitude. Obesity, type 2 diabetes, and peripheral vascular disease, independent predictors of CVC use, are growing problems globally, which could lead to more difficulties in native arteriovenous fistula placement and survival.

Nevertheless, in the USA following the establishment of the Fistula First Initiative, AVF use among prevalent HD patients increased steadily from 34.1% in December 2003 to 60.6% in April 2012.(31) In incident patients, VA statistics at the start of chronic HD in 2009 were the following: AVF in use 14.3%; AVG in use 3.2%; CVC in use 81.8%; AVF maturing 15.8%; AVG maturing 1.9%.

International data from DOPPS has shown large variations in VA practice(32) and greater mortality risks have been seen for HD patients dialyzing with a catheter, while patients with usable AVF have the lowest risk.(33) International trends in VA practices have been observed within the DOPPS Study from 1996 to 2007.(32) Between 2005 and 2007, a native AVF was used by 67–91% of prevalent patients in Japan, Italy, Germany, France, Spain, the

UK, Australia and New Zealand, and 50–59% in Belgium, Sweden and Canada. From 1996 to 2007, AVF use rose from 24% to 47% in the USA but declined in Italy, Germany and Spain. Across three phases of data collection, patients consistently were less likely to use an AVF versus other VA types if female, of older age, having greater body mass index, diabetes, and peripheral vascular disease. In addition, countries with a greater prevalence of diabetes in HD patients had a significantly lower percentage of patients using an AVF. Despite poorer outcomes for CVC, catheter use rose 1.5- to 3-fold among prevalent patients in many countries from 1996 to 2007, even among non-diabetic patients 18–70 years old. Furthermore, 58–73% of incident patients used a CVC for the initiation of dialysis in five countries despite 60–79% of patients having been seen by a nephrologist more than 4 months prior to ESRD. The median time from referral until access creation varied from 5–6 days in Italy, Japan and Germany to 40–43 days in the UK and Canada. Surgery waiting time, along with time from access creation until first cannulation, significantly affected the possibility of starting HD with a permanent access. (32)

Surprisingly, patient preference for a CVC also varied across countries, ranging from 1% of HD patients in Japan and 18% in the United States, to 42% to 44% in Belgium and Canada.(34) Preference for a CVC was positively associated with age, female sex, and former or current catheter use. The observed considerable variation in patient preference for VA suggests that patient preference may be influenced by sociocultural factors and thus could be modifiable.

The use of CVCs carries a significant risk for serious complications. Lately, in non-renal patients the peripherally inserted central venous catheter (PICC) has gained in popularity due to presumed advantages over other CVC.

Early referral of ESRD patients to the nephrologist is strongly recommended. This approach may minimize the use of catheters and reduce catheter-related morbidity and need for hospitalization.(35) Early referral to the nephrologist is also required for psychological preparation for dialysis, discussion of for dialysis modality options, interventions to delay

progression of renal damage and to correct hypertension, anemia and metabolic effects of renal failure.(36) Time from referral to surgery for AV access creation should also be as short as possible.(32)

CHAPTER III

Clinical Decision Making

3.1. Choice of vascular access

Successful HD treatment is only possible with a well-functioning VA. The ideal vascular access should allow cannulation using two needles, deliver a minimal blood flow of at least 300 ml/min through the artificial kidney, is resistant to infection and thrombosis and have minimal adverse events. The first option for the construction of a VA is the creation of an autogenous arteriovenous fistula (AVF). Secondary and tertiary options are prosthetic arteriovenous grafts (AVG) and CVCs. The reason to create autogenous AVFs is that observational studies show a lower incidence of postoperative complications and fewer endovascular and surgical revisions for AVF failure in comparison to AVGs.(37) In addition, the use of CVCs results in a significantly higher morbidity and mortality rate. The hospitalization risk for access-related reasons and particularly for infection is highest for patients on HD with a catheter at initiation and throughout follow-up.(38) The principle of venous preservation dictates that the most distal AV fistula possible should usually be performed.(39)

The strategy is to start HD in incident patients with a distal autogenous AVF preferentially in the nondominant upper extremity. In cases of a failed distal access a more proximally located AVF can be performed.

3.2. Timing of referral for vascular access surgery

Timely patient referral to the VA surgeon for access creation is of importance for the outcome of the access. Early referral results in more and well-functioning autogenous AVFs(40), while late referral results in a greater chance on AVF nonmaturation and the need for CVC for HD. (41-43) Also, HD initiation with a CVC and a long AVF maturation time, results in poorer long-term patency rates of AVFs. The same factors that predict worse primary AVF survival are also associated with greater risk of final failure. The presence of cardiovascular disease,

utilization of catheters at HD initiation, and early cannulation are independent predictors of final failure. A lower cut-off level of time to cannulation is associated with the greatest risk of final failure. (40) (Fig. 2 and 3) Frequent pre-nephrology visits (PNV) are related to improved patient survival during the first year after initiation of HD, indicating the possible survival benefit with increased attention to PNV, particularly for elderly and diabetic patients. (44, 45) From the DOPPS data, great differences between the European countries in referral type and time of access creation, have been reported. Planning of access surgery varies between < 5 days (Italy) to > 42 days (UK) after referral to the VA surgeon.(32) The knowledge and experience of the VA surgeon is of importance to create predominantly autogenous fistulas and has a major impact on the outcome of surgery.(46, 47) However, there remain large regional differences between hospitals, concerning the number of autogenous AVFs created and the chance on successful maturation.(48)

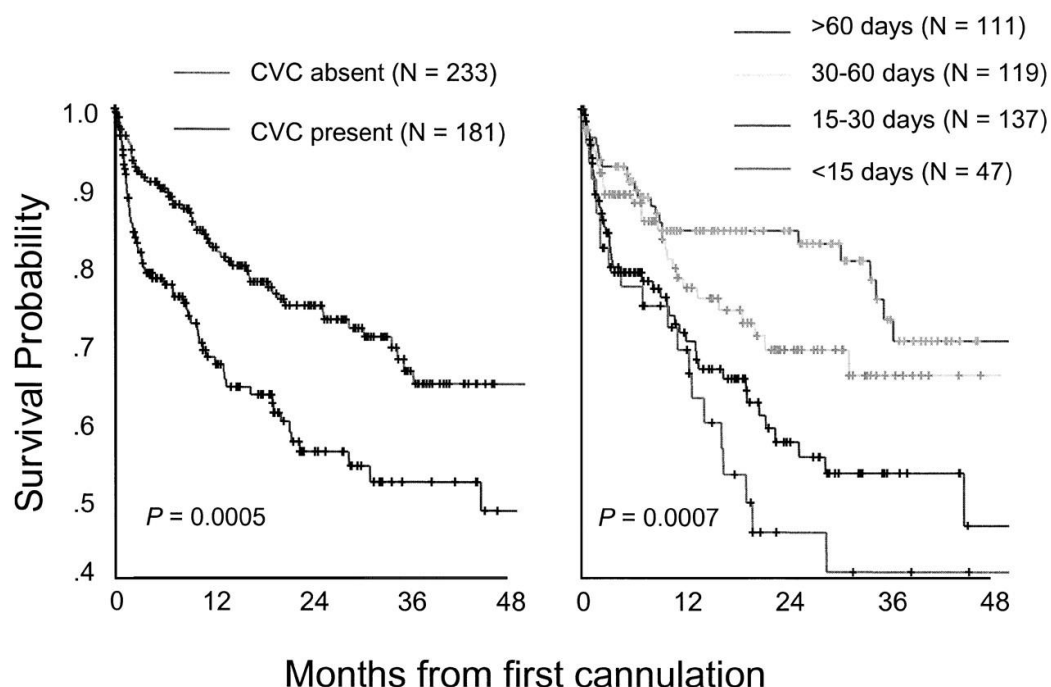


Fig. 2. Kaplan-Meier curves of time to AVF failure (primary patency from first cannulation) by use of catheters (CVC) at the initiation of HD (left) and by the time to maturation in days (right).(40)

**Cox's models
of time to AVF failure**

**Variables in the equations
with the associated HRs (95%CI)**

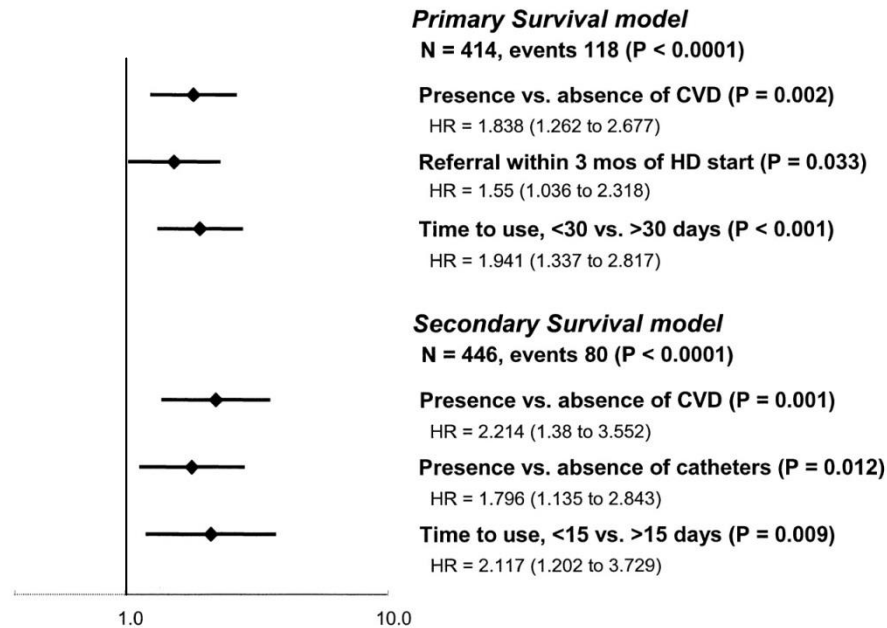


Fig. 3. Risk factors associated with primary and secondary access failure.

Hazard ratios plotted using a logarithmic scale (cardiovascular disease=CVD).(40)

3.3. Selection of modality of vascular access

3.3.1. Primary option for vascular access - autogenous arteriovenous fistula

The radial-cephalic AVF at the level of the wrist (RCAVF) is the first choice to create VA.

When successfully matured, the RCAVF can function for years with a minimum of complications, revisions and hospital admissions. The RCAVF is preferentially created in the nondominant arm, but the dominant extremity may be chosen if the vessels in the nondominant arm are unsuitable. The indication to perform a wrist RCAVF depends on the outcome of physical examination (inspection and palpation of distal veins and arteries) and additional ultrasound examination. A minimal internal vessel diameter for both radial artery and cephalic vein of 2.0 mm (with proximal tourniquet) is considered to be adequate for successful fistula creation and maturation. For brachio-cephalic and brachial-basilic AVFs a minimal arterial and venous diameter of 3 mm would be sufficient.

Major disadvantages are the risk of early thrombosis and non-maturation and, ultimately, access failure. A meta-analysis showed a mean early failure percentage of 17%.(49) However recent studies have shown higher failure rates of up to 46% with one year patencies from 52 to 83% (Table 5). An elderly dialysis population with concurrent comorbidities and poor upper extremity vessels, resulting in more RCAVF failures, is the reason for these high early failure percentages.(50)

When a wrist RCAVF is not possible or has failed, a more proximally located AVF in the forearm, antecubital region or upper arm may be performed. These accesses are called mid-forearm, brachial /radial-deep perforating vein(51), brachial-median cubital vein, brachial-cephalic (BCAVF) and brachial-basilic AVFs (BBAVF). Brachial artery-based AVFs deliver a high access flow which is favorable for high HD flows, but may result in low distal arterial perfusion and cardiac overload.(52) These types of AVFs have good one year patencies (Table 6 and 7) with a low incidence of thrombosis (0.2 events per patient/ year) and infections (2%).

If direct arteriovenous anastomoses are impossible, vein transposition/translocation can be performed, with redirection of a suitable vein to an available artery (forearm radial/ulnar-basilic AVF) or greater saphenous vein harvesting from the leg and subsequently implantation between an arm artery and vein (see Chapter VIII).

A BVT in the upper arm is a good choice when RCAVFs or BCAVFs have failed. BBAVFs can be performed in either one or two-stage operations.

Table 5. Early failure and one-year secondary patency rate of radial-cephalic AVF

Reference	No. RCAVF	Early failure (%)	Secondary patency (%)
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Silva et al (53)	108	26	83
Golledge et al (54)	107	18	69
Wolowczyk et al (55)	208	20	65
Gibson et al (56)	130	23	56
Allon et al (57)	139	46	42
Dixon et al (58)	205	30	53
Ravani et al (59)	197	5	71
Rooijens et al (60)	86	41	52
Biuckians et al (61)	80	37	63
Huijbregts et al (50)	649	30	70

Table 6. Early failure (within one month of access creation) and one-year secondary patency rate of brachial-cephalic AVF (including brachial- cephalic/perforating vein AVF)

Reference	No.BCAVF	Early failure (%)	Secondary patency (%)
Murphy et al (62)	208	16	75
Zeebregts et al (63)	100	11	79
Lok et al (64)	186	9	78
Woo et al (65)	71	12	66
Koksoy et al (66)	50	8	87
Palmes et al (67)	55	9	89
Ayez et al (68)	87	8	83

Table 7. Early failure (within one month of access creation) and one-year secondary patency rate of brachial-basilic AVF

Reference	No.BBAVF	Early failure (%)	Secondary patency (%)
Murphy et al (62)	74	3	75
Segal et al (69)	99	23	64
Wolford et al (70)	100	20	47
Arroyo et al (71)	65	8	88
Keuter et al (72)	52	2	89
Koksoy et al (66)	50	8	88
Field et al (73)	140	19	69
Ayez et al (68)	86	6	73

3.3.1.1. Patient variables and outcome of vascular access

Various studies have showed an important influence of patient variables on choice and outcome of VA. Age and diabetes mellitus negatively influence fistula maturation and increase the risk of AVF failure.(74)

A very recent systematic review of the literature showed a tendency towards increased risk for deep vein thrombosis and a decreased risk for catheter occlusion with PICC.(75) An anatomical region at high risk for thrombosis is the antecubital fossa. Elbow veins represent a valuable source for the creation of a VA for HD, especially in obese patients, elderly patients, diabetics and patients affected by peripheral artery disease.(76) Such veins should be preserved (see Recommendation 14, Chapter V).(43)

Women usually have smaller vessels than men, which may result in poorer maturation and lower long-term patencies. Some studies do show that females need more access revisions and the creation of more AVGs (56, 77-82), while others, including a meta-analysis, could not prove any significant differences in vessel diameters and the chance on maturation between man and woman.(49, 83)

Diabetes mellitus and arteriosclerosis are the most important causes for renal failure and HD treatment and can have a negative influence on successful use of the VA.(79) Other

variables that influence fistula use are: peripheral arterial occlusive disease (PAOD), race and obesity.(84)

Patients using calcium channel blockers, aspirin and ACE inhibitors, have a better patency of AVFs and AVGs.(85)

3.3.2. Secondary option for vascular access

When there are no options to create an autogenous AVF, an arteriovenous graft fistula with the implantation of synthetic (ePTFE; polyurethane; nanograft = electrospun ePTFE graft) or biologic material (ovine graft/ Omniflow[®]) can be created. ePTFE is frequently used as an AVG with reasonable short-term patencies but long-term patencies are hampered by thrombotic occlusions, due to stenoses caused by progressive intimal proliferation. One and two-year primary patencies vary between 40 to 50% and 20 to 30%, respectively. The secondary patency varies from 70 to 90% (at one year) and 50 to 70% (at 2 yrs.). Multiple interventions to prevent and treat thrombosis are required, to achieve these patencies.(86-90)

Elderly patients may benefit from the use of AVGs, because of a high primary failure of autogenous AVFs in these patients.(91) An important consideration for AVG use (in particular “early stick grafts”) might be the avoidance of CVCs with their inherent high infection risk, in particular when (sub)acute HD treatment is necessary and AVF creation/maturation is problematic.

3.3.3. Lower extremity vascular access

The indications for lower extremity VA are bilateral COVD or inability to create access in the upper extremity. Primary options are autogenous greater saphenous (92) and femoral vein transpositions (FVT) (93), and prosthetic graft implantation. Thigh accesses have acceptable patencies with as disadvantage the risk on ischemia and infection.(94)

In a meta-analysis the results of femoral vein and AVGs are described. The one year primary and secondary patency was 83 and 48% and 93 and 69%, for FV and grafts respectively.

Access loss due to infection was primarily seen in AVGs (18% vs. 1,6%; $P<0,05$). Ischemia occurred more in AVFs compared to lower extremity AVGs (21% vs. 7,1%, $P<0,05$).⁽⁹⁵⁾ Recently, the outcome of 70 FV accesses was published with good results but a 18% incidence of critical ischemia, for which revisional surgery was indicated.⁽⁹⁶⁾

3.3.4. Indications for a permanent catheter for vascular access

Temporary CVCs are frequently used for acute HD or as bridging access during fistula maturation and complications. Permanent tunneled CVCs may be indicated in patients with severe access-induced ischemia, cardiac failure or limited life expectancy. Patients with peritoneal dialysis (PD) peritonitis or waiting for a planned living-related renal transplant can also be dialyzed through a CVC for a limited time period.

The primary location for a CVC is the right internal jugular vein with subsequently the left jugular, femoral and subclavian vein as alternative insertion locations. Femoral and subclavian vein CVCs should only be used for short time periods, because of risk of infection and COVD.

Recently, HD via a CVC has increased in the USA, Canada and Europe, with a significantly higher risk of morbidity and mortality due to infectious complications in comparison to the use of AVFs and AVGs (Fig. 4).^(97, 98)

The reason of increased CVC use is the inability to create functioning AVFs because of poor vessel quality in the elderly, comorbid population.

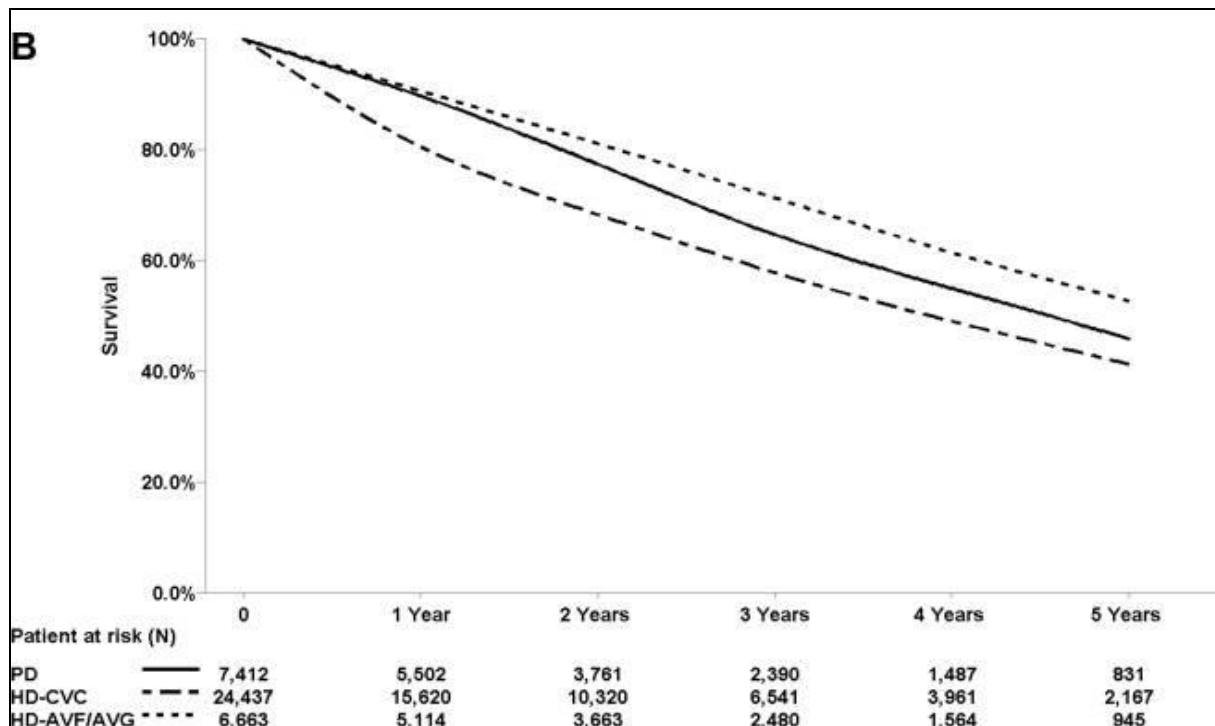


Fig. 4. Survival (%) of patients with PD versus HD-CVC and HD-AVF/AVG.(98)

Recommendation 1

Referring chronic kidney disease patients to the nephrologist and/or surgeon for preparing vascular access should be considered when they reach stage 4 of chronic kidney disease ($\text{GFR} < 30 \text{ ml/min per } 1.73 \text{ m}^2$), especially in cases of rapidly progressing nephropathy. Class I, Level C, Ref. (43, 99)

Recommendation 2

A permanent vascular access should be created 3 to 6 months before the expected start of hemodialysis treatment. Class I, Level B, Ref. (40, 42-44, 99)

Recommendation 3

An autogenous arteriovenous fistula is recommended as the primary option for vascular access. Class I, Level B Ref. (37, 38)

Recommendation 4

The preferred vascular access is a radial-cephalic arteriovenous fistula. Class I, Level A Ref. (37, 39, 50, 52)

Recommendation 5

The non-dominant extremity is preferred for vascular access creation when vessel suitability is sufficient. Class IIa Level C Ref. (37, 50, 52)

Recommendation 6

A lower extremity vascular access is advised only when upper extremity access is impossible. Class IIa, Level B, Ref. (93, 95, 96)

Recommendation 7

Permanent central venous catheters should be considered when the creation of arteriovenous fistulas or grafts is impossible or in patients with limited life expectancy. Class IIa, Level B, Ref. (97, 98)

CHAPTER IV

Preoperative imaging

4.1. Preoperative assessment

Besides a detailed preoperative history and physical examination, non-invasive ultrasound imaging plays an important role in VA selection. Preoperative duplex ultrasonography (DUS) enhances the success of creation and the outcome of autogenous AVFs.(100) In a randomized trial, a primary failure rate of 25% without pre-operative DUS was observed in comparison with a failure rate of 6% with DUS.(101) Ultrasound venous mapping allows a precise evaluation of the depth of vascular structures(102) and detects VA sites that may be missed by clinical examination alone.

Especially in patients where physical tests suggest impaired arterial inflow, DUS assessment can measure arterial diameters and flow as well as revealing stenotic segments.(103)

In addition, DUS identifies patients with inadequate vessels in specific access locations. In a study of 211 consecutive patients DUS found that 50% of them had an inadequate arterial inflow for a distal RCAVF creation.(104)

DUS provides helpful information before AVF construction such as internal vessel diameters and internal venous lesions.(105) Currently, a minimal internal diameter of 1.6 mm for arteries and 2.0 mm for veins is recommended preoperatively before RCAVF-creation and 4.0 mm for AVG-implantation.(43) Furthermore DUS provides important information for the planning of potential future AVF superficialization.

DSA is helpful in only a small group of selected patients with significant peripheral vascular disease and suspected proximal arterial stenosis, where the preoperative endovascular approach allows identification and treatment in one procedure. However, the risk of potential contrast-induced nephropathy must be carefully considered if iodinated contrast is used.(106)

Contrast enhanced MR angiography (CE-MRA) is now contraindicated, since Gadolinium use is associated with the potential risk of a nephrogenic systemic fibrosis, especially in patients with severely impaired renal function.(107) However, CE-MRA enabled accurate pre-operative detection of upper extremity arterial and venous stenosis and occlusions.(108, 109) Promising initial data for the pre-operative visualization of arterial and venous vascular structures by non-contrast MRA are available.(110)

In patients with a history of previous CVCs additional preoperative imaging of the central veins may be beneficial, e.g. by venography.(43)

Recommendation 8

Preoperative non-invasive ultrasonography of upper extremity arteries and veins should be performed in all patients. Class IIa, Level B, Ref. (100-102)

4.2. Imaging methods for vascular access surveillance and maintenance

4.2.1. Duplex ultrasound

Duplex ultrasonography (DUS) as non-invasive procedure is the first line imaging method in patients with suspected VA dysfunction.(43, 111, 112) However the diagnostic quality of DUS depends strongly on the experience of the examiner (113-115) and provides no angiographic map for the guidance of further therapy.(116) DUS locates and quantifies stenosis, allows flow measurements and detects thrombotic occlusions (117-121) but evaluation of the central veins may be limited.(112)

DUS is a cost-effective technique for the evaluation of VA maturation, surveillance and complications.(122-124) If CVOD cannot be reliably excluded by DUS, additional imaging methods (e.g. DSA) will be necessary. Surveillance by DUS is reported to prolong AVG survival.(125) Only a few studies are available on DUS as an interventional diagnostic tool

for ultrasound-guided PTA of failing or non-maturing VA, which may be particularly indicated in patients with iodine contrast allergy or with residual kidney function.(126, 127)

Although VA infection is primarily diagnosed clinically(128) DUS can supplement information of extent of infected perivascular tissue and associated thrombosis.

Recommendation 9

Duplex ultrasound is recommended as first line imaging modality in suspected vascular access dysfunction. Class I, Level A, Ref. (43, 111-115, 129)

4.2.2. Computed tomography

Multi-slice computed tomography requires the use of iodinated contrast and radiation and should therefore only be used if no equivalent technique is available. However, compared to DSA CTA is a less-invasive technique that provides important information for further treatment (surgery or PTA) and is less expensive than purely diagnostic DSA.(130) CTA is a reproducible and reliable technique for the detection of $\geq 50\%$ stenosis or occlusion in dysfunctional AVF (131) and showed excellent correlation in stenosis detection compared to DSA.(132) CTA allows the evaluation of the vascular tree in failing VA before treatment (132), especially if supplemented by 3D image reconstructions.(133)

Concerning forearm AVF, CTA provides a good VA visualization with moderate sensitivity and high specificity for the detection of flow-limiting stenosis.(134) For the detection of CVOD the sensitivity of CTA is dependent on the applied examination protocols. In suspected CVOD CTA should be considered only when ultrasonography or DSA are inconclusive, e.g. for the evaluation of the central veins and visualization of the vascular tree.(135)

Recommendation 10

Computed tomographic angiography should be considered in patients with inconclusive ultrasonography results. Class IIa, Level C, Ref. (132-135)

4.2.3. Magnetic resonance imaging (MRI)

Gadolinium may cause nephrogenic systemic fibrosis (NSF) in patients with advanced impairment of renal function under HD. Therefore CE-MRA should be used only after carefully weighing the risks and benefits of alternative imaging studies.(107)

Even in the era before NSF had been recognized, CE-MRA had not replaced ultrasonography or DSA for preoperative evaluation, but was believed to be appropriate in selected cases.(108, 136) It allows non-invasive examination of the arterial and venous system.(137, 138) Due to the absence of MR-guided VA interventions, CE-MRA is currently used as a purely non-invasive diagnostic tool and potential treatment must be performed by additional percutaneous intervention or surgery.(139)

In comparison with DSA in complex AVF, fewer complications and side-effects were observed by the use of CE-MRA.(140)

In another CE-MRA study, a sensitivity of 100% and a specificity of 94% were observed for the arterial and venous trees.(141) In addition, CE-MRA showed high sensitivity, specificity and positive and negative predictive values in the detection of stenosed vessel segments of dysfunctional AVF and AFG.(137) Non-contrast-enhanced MRA is an evolving technology that has been proposed to avoid the risk of NSF. Preoperative mapping and postoperative evaluation of the VA have shown promising results in the prediction of failure.(110, 142) To the knowledge of the authors, there are no data for the non-contrast MR evaluation of VA dysfunction so far.

Recommendation 11

Contrast enhanced MRA is not recommended in patients with end stage renal disease, because of the potential risk of Gadolinium associated nephrogenic systemic fibrosis. Class III, Level C, Ref. (107)

4.2.4. Digital Subtraction Angiography (DSA)

In patients with VA dysfunction pure diagnostic DSA without subsequent intervention is not advised.(112) In selected cases, DSA may be used in pre-operative vein mapping, e.g. when central stenosis or occlusion is suspected or for the surveillance of CVOD, since venography is superior to DUS in the detection of CVOD.(117) In addition, DSA offers the opportunity to identify and treat central lesions during the same procedure.(143) During endovascular treatment and after surgery, DSA is performed to detect inflow, intra-access and outflow stenoses as well as residual stenoses or remaining clots(144) and to reveal CVOD.(143)

Iodinated contrast agents can cause further deterioration of residual renal function.

Nevertheless, DSA with dilute iodinated contrast can be performed relatively safely even in patients with end stage kidney disease.(106) However, CO₂ angiography is an effective alternative, without the risk of further impairment of renal function. CO₂ angiography has a sensitivity of 97% and a specificity of 85% in the evaluation of upper limb and central vein stenosis in comparison with conventional venography.(145) Due to the acceptable results of CO₂ angiography and the potential risk of NSF gadolinium enhanced DSA(146) is no longer indicated.

Recommendation 12

In vascular access dysfunction digital subtraction angiography should be performed only for patients with expected subsequent interventions. Class I, Level C.(112)

Chapter V

Creation of vascular access

5.1. Technical aspects

5.1.1. Venous preservation

It is essential to preserve the veins of the forearm in patients who are at risk of CKD as they may require HD in the future.(39, 147) Patients and their carers should be instructed to avoid intravenous cannulae and where possible venipunctures in the cephalic or antecubital veins of either arm. If an intravenous cannula is unavoidable, it should preferably be inserted into the veins on the dorsum of the hand to avoid thrombophlebitis of the forearm and upper arm veins. The number of available veins for further access is also maximized by a policy of performing an AVF at the most distal site available.

Recommendation 13

In patients undergoing or likely to require hemodialysis, intravenous cannulae and venipuncture of the cephalic veins and the antecubital veins may be harmful and should not be performed. Class III Level C, Ref (35, 36, 39, 147)

5.1.2. Arm exercises

Arm exercises have been shown to improve arterial and venous diameters and resting blood flow in the upper limb in comparison with the opposite rested arm in patients with renal failure.(148) Whilst this is likely to be beneficial, it is not yet known whether preoperative arm exercise improves AVF patency or maturation (although postoperative exercise with a tourniquet has been shown to increase maturation(149) as discussed in Chapter VI).

5.1.3. Preoperative or perioperative hydration

Hypotension is a known adverse factor in fistula survival(150) and may also cause early thrombosis. Rehydration with plasma expanders during access creation improved primary patency of AVFs in a randomized study of patients with borderline vessels (151)

Recommendation 14

Patients should be adequately hydrated before or during vascular access creation. Class I, Level B, Ref (150, 151)

5.1.4. Prophylactic antibiotics

There is little evidence concerning the use of prophylactic antibiotics and the creation of VA. However, several randomized trials have shown that preoperative broad-spectrum antibiotic administration reduces the incidence of wound or graft infection in other vascular surgical procedures by approximately 70%.(152) In a small randomized trial cefemandle significantly reduced infection after AVG insertion.(153) Another randomized trial showed that a single 750mg preoperative dose of intravenous vancomycin significantly reduced the rate of infection in AVGs from 6% to 1%.(154)

Whilst the incidence of wound infection is greater in the lower limb than the arm, a broad spectrum antibiotic with activity against staphylococci, such as a cephalosporin, amoxycillin/clavulanic acid or a glycopeptide, is recommended preoperatively for all VA operations to cover any other focus of infection in the patient, especially in diabetics or if a prosthetic graft is to be used. When the local prevalence of methicillin-resistant staphylococcus aureus (MRSA) is significant or the patient is a known MRSA carrier, a parenteral glycopeptide such as vancomycin or teicoplanin should be considered. In known carriers of other multiresistant organisms such as extended-spectrum beta-lactamase producing organisms (ESBL) an appropriate antibiotic, such as a carbapenem, should be considered according to the bacterial sensitivities.

Recommendation 15

Broad spectrum antibiotics should be given prior to insertion of an arteriovenous graft including prophylaxis for staphylococcus aureus. In carriers or in units with a high incidence of methicillin resistant staphylococcus aureus cover should be considered. Class I, Level A, Ref (152-155)

Recommendation 16

Broad spectrum antibiotics should also be considered prior to other vascular access surgical procedures including arteriovenous fistula construction, especially in the lower limb. Class IIb, Level C, Ref (155)

5.1.5. Preoperative antiplatelet agents

Evidence concerning the use of antiplatelet agents is incomplete. As discussed more fully in a later section, three meta-analyses have favored antiplatelet agents to reduce VA thrombosis, but the few existing trials have differed in both the drugs and the mode of administration and whether they were given to patients with AVFs or grafts. Moreover, in most trials the antiplatelet agents were only administered postoperatively (156-158) Amongst the 19 trials cited in the most recent meta-analysis(158) there were only three trials in which antiplatelets were administered consistently before surgery: In one trial aspirin caused a significant reduction in perioperative fistula thrombosis(159), in the second clopidogrel was associated with a significant reduction in primary failure of AVFs although maturation was unaffected(160) but in the third the 35% reduction in primary fistula failure with ticlopidine administration failed to reach significance.(161) Despite the heterogeneity of these trials, it would seem advisable to give aspirin or another antiplatelet agent preoperatively and continue postoperatively in an attempt to reduce access thrombosis.

5.1.6. Preoperative physical examination

Prior to surgery the upper limb pulses and superficial veins should be examined clinically by an experienced clinician with and without a venous tourniquet in a warm room in order to ensure maximum vasodilatation. The patient should also be examined for signs of venous hypertension in the limb such as prominent and tortuous collateral veins around the shoulder and upper limb edema. The site of any CVC or pacemaker should be noted.(162) The chosen site for the fistula should be marked with a permanent marking pen.

Recommendation 17

Patients should be examined prior to surgery with a tourniquet in a warm room and the proposed site of an arteriovenous fistula should be marked preoperatively. Class I, Level C, Ref(162)

5.1.7. Anesthesia

The majority of AVFs and many AFGs in the forearm or in the antecubital fossa can easily be performed under local-regional anesthesia such as lidocaine or bupivacaine initiating a sympathetic blockage and leading to dilation with higher perioperative access flows and thereby probably better early results.(163). Regional anesthesia such as axillary or brachial block takes more time and usually requires the services of an experienced anesthetist but has the advantage of causing significant vasodilatation(164, 165), which some surgeons find helpful and increase the proportion of distal AVFs in their hands.(166-168) In one randomized trial, stellate ganglion block significantly increased fistula flow, increased early patency and reduced maturation time.(169) More extensive access procedures such as basilic vein transposition, brachio-axillary grafts or lower limb access usually require either regional blockade or general anesthesia.

Whilst regional blockade may have advantages, there is no evidence to suggest whether the mode of anesthesia influences subsequent patency and, in one non-randomized study, regional anesthesia and general anesthesia resulted in similar early patencies of brachio-cephalic and brachio-basilic AVFs.(170)

Recommendation 18

Local or regional anaesthesia should be considered as first choice for upper limb vascular access surgical procedures. Class IIa, Level C, Ref (163-168)

5.1.8. Microsurgery and tourniquet use

Whereas duplex studies have suggested that AVF patency is poor if the internal arterial diameter is less than 1.6-2mm and the venous diameter is less than 2mm(171), excellent patencies have been obtained for AVF creation using smaller vessels in both adults and children using microsurgery and a tourniquet.(172, 173)

5.1.9. Perioperative anticoagulation

Perioperative anticoagulation with systemic heparin is widely used in vascular surgery to prevent intravascular thrombosis during clamping of the vessels. In two randomized trials, systemic heparinization (5000 IU intravenously) did not affect subsequent AVF patency but increased the incidence of postoperative hemorrhage.(174, 175) In contrast, a third randomized trial found systemic heparin improved early patency without increasing complications.(176) Following a recent meta-analysis of these three trials it was concluded systemic heparin had no effect on patency but significantly increased postoperative hemorrhage and therefore should be avoided.(171) Nevertheless, units employing tourniquets report no increase in bleeding with systemic heparinization.(172) Local instillation of heparinized saline or Ringer's solution into the vessels or AVG after clamping is the usual practice in most units.

5.1.10. Arteriovenous fistula configuration

For AVFs an end to side (vein to artery) configuration is preferred as it allows easier approximation of the vein and artery and avoids the risk of distal venous hypertension without affecting patency.(177) For RCAVFs an end to end anastomosis has been advised by some to prevent steal syndrome(178) but the incidence of steal in distal AVFs is very low

and in the rare occasions where it does occur it can easily be treated by ligation of the distal radial artery under local anesthetic provided that the ulnar artery is patent.(179, 180) Moreover, the radial artery usually remains patent after thrombosis of the access and provides the blood supply to the hand.

5.1.11. Surgical techniques

It is generally agreed that an AVF should be performed at the most distal site possible, provided the vessels are adequate in order to preserve as many vessels as possible (see Chapter III).(39, 181) Whilst proximal AVFs have been shown to have a lower initial failure rate and better patency than distal AVFs, as would be expected from larger vessels(182, 183), they have a greater risk of steal(184), may be more difficult to cannulate and are less comfortable for the patient.

Whilst the non-dominant arm is usually preferred, if a pacemaker or CVC is present the contralateral side is preferred because of the risk of venous hypertension and possible reduced fistula patency.(185) However, when contralateral access is impossible, preoperative central venous imaging is advised to confirm free venous flow prior to surgery. Lower limb access is the last option as it has a greater infection risk(95), is less convenient and less comfortable for the patient.

Recommendation 19

In adults when the inner arterial diameter is less than 1.6mm and/or the venous diameter is less than 2.0mm an alternative site for access should be found unless the surgeon is expert in use of microsurgery under tourniquet. Class IIa, Level B, Ref (171, 186)

Recommendation 20

If there is an indwelling central venous catheter or pacemaker the vascular access should be created in the opposite arm because of the risk of central venous stenosis. Class I,

The first choice for an access is either a snuffbox or RCAVF at the wrist which have similar patency in selected patients.(55, 187) A RCAVF may be created at any level in the forearm if the wrist vessels are inadequate or thrombosed but, if this is not possible, a BCAVF would usually be the next choice. In a meta-analysis of fistula patency RCAVFs had poorer patency in the elderly suggesting that a BCAVF might be preferred in such patients(91) but subsequent large series have failed to show any patency difference(188, 189) and excellent results have been reported for RCAVFs in the elderly in several units.(55, 190) Thus, which VA should be performed in the elderly will be determined by patient characteristics and physician or surgeon preference.

Several configurations of BCAVF are possible(39) using the cephalic vein, the confluence of the cephalic and basilic veins or the deep perforating vein but there is no evidence that one configuration has better patency. The “extension” procedure, which replaces the anastomosis to the brachial artery with one to the radial artery 2cm from the origin, is technically more demanding but may have a lower risk of steal.(191) There is a 12% incidence of a high brachial bifurcation so that the ulnar and radial arteries are both present in the cubital fossa. (192) The larger of the two arteries should be used for the anastomosis, but, nevertheless, the overall patency may be less than that of standard BCAVFs.(193) An ulno-basilic AVF is also an option although the patency is poorer than for RCAVFs.(194) Various transposition AVFs are also possible in the forearm (eg ulno-cephalic or radio-basilic).(195)

When the veins of both forearms are exhausted, a basilic vein transposition AVF (BVT) is usually preferred to a forearm loop graft or a brachio-axillary graft because of its better patency. (72, 196-199) and lower infection rate .(200, 201) Whether, this should be performed in one stage or two stages is not settled: Three non-randomized studies (202-204) and one small randomized study (204, 205) have had conflicting results in terms of patency but in one study complication rates were less with a two-stage procedure. In case of small

basilic vein diameters two-stage operations may be advantageous to enhance maturation. A meta-analysis of 1509 patients showed clearly the preference for creating BBAVF instead of AVGs. Pooled secondary patencies were 67% vs 88% for AVGs and BBAVFs, respectively. The number of reinterventions was significantly higher in patients with AVGs (1.32 versus 0.54 per patient/year).(197) However, any advantage of the two stages must be balanced against the 6 week delay between operations as well as the extra cost and inconvenience for the patient. BVT using endoscopic basilic vein harvest has been described and reported to reduce hospital stay without compromising patency in a non-randomized study.(206) When the basilic vein is inadequate, the brachial veins or venae comitantes can be used but the patency was poorer in some studies.(207-210) Satisfactory results with transposed saphenous or femoral vein in the arm has been described in small series but there are no studies directly comparing them with AVGs.(211, 212)

When autogenous options in the arms have been exhausted, AVGs in various configurations such as forearm loops and brachio-axillary grafts increase the possibilities in the upper limb.

Recommendation 21

When the upper arm cephalic vein is unavailable, a basilic vein transposition arteriovenous fistula should be considered in preference to an arteriovenous graft because of its improved patency and the reduced risk of infection. Class IIa, Level B, Ref (72, 196, 198-201)

Lower limb access is reserved for patients with no remaining options in the arms as it is less comfortable for the patient and has a greater risk of steal and infection(95, 213) (see chapter III) Femoral vein transpositions are preferred over AVGs in the thigh because of better primary patency and lower infection rates (see Chapter III).(95, 101, 204) However, ischaemia was much more frequent for femoral vein transpositions (95) but it was eliminated in a small series by avoiding them in patients with reduced ABI (<0.85) and by tapering the vein at the anastomosis to reduce its diameter to 4.5 - 5mm.(93) There is little

evidence on the use of saphenous vein thigh loops and, whilst these have been generally regarded as having poor patency(95), a recent series of 56 saphenous vein transpositions in the thigh reported an acceptable primary patency of 44% at 59 months.(92) When prosthetic access is necessary in the thigh, there appears to be no significant difference in infection rates or patency between mid and upper thigh AV loops.(95, 214)

Recommendation 22

When lower limb vascular access is necessary a femoral vein transposition should be considered in preference to an arteriovenous graft. Class IIa, Level B, Ref (95, 214)

5.1.12. Choice of graft

Both synthetic and biological grafts are available and have been used for VA. In general, synthetic grafts have been generally preferred because of lower cost and anxieties about long term degeneration in biological grafts, although the latter have a greater resistance to infection and may be preferred in contaminated fields.(215)

Expanded PTFE (ePTFE) grafts are the most widely used. There is some evidence from randomized studies that primary patency is better for grafts with an expansion at the venous end (216, 217) and non-randomized studies suggesting that heparin-bonded grafts may also have better patency.(218) One randomized study has also shown reduced thrombosis with a vein cuff at the venous end of a ePTFE graft although the improvement in primary patency failed to reach statistical significance(219) There is no evidence that patency is affected by carbon coating, or by external or internal support although the latter may prevent kinking. Most surgeons use 6mm grafts although there is no evidence to support this over other diameters. Stepped or tapered grafts have no proven advantage despite hopes that they might reduce steal whilst preserving patency. Most prosthetic grafts can be used after 1-2 weeks although newer multilayer ePTFE grafts are self-sealing and can be safely needed within 1-2days(220, 221), which can avoid the use of CVCs in some patients.(222) A polyurethane graft also may be used within 1-2 days of insertion and has been reported to have similar patency to BVT and ePTFE(223, 224) but had an increased risk of infection than

ePTFE in one non randomized study.(213, 224) A removable plastic sheath prevents stretching during tunneling, thereby reducing perigraft seroma caused by “sweating” and improved patency in one non-randomized study (‘Slider’ graft).(225) A biosynthetic graft consisting of a collagen-polyester composite gave acceptable results in one small observational study(226) but had significantly poorer primary patency than brachio-basilic AVFs in a small randomized study.(196)

Because there are no comprehensive randomized studies comparing several grafts no definite recommendations can be made concerning which graft should be used routinely but a self-sealing graft would be advisable for patients with difficult central venous access and who require early HD.

Combining a standard ePTFE graft at the arterial end with a CVC inserted percutaneously (“HeRO” graft) may be a useful alternative to a central venous line in patients with inadequate upper limb veins(227, 228) although whether it is preferable to a lower limb access is uncertain (see chapter VIII).

Biological grafts such as bovine carotid artery or bovine mesenteric vein, which have been rendered immunologically inert, have been used extensively in some units(215) and have compared well with prosthetic grafts in one small randomized study(229) and a further non-randomized study(230) but their relatively high cost and fears of long term aneurysm formation and rupture have limited their usage. Tissue engineered grafts have been used in a small number of patients but it is too early to determine whether these have any advantages over other grafts.(231)

Recommendation 23

When an arteriovenous fistula cannot be created, a biological graft should be considered in preference to a synthetic graft in the presence of infection. Class IIa, Level C, Ref (215, 229, 230)

Recommendation 24

The implantation of a self-sealing arteriovenous graft is recommended for patients with difficult central venous access and who require early cannulation for hemodialysis. Class I, Level C, Ref (222)

5.1.13. Sutures or nitinol anastomotic clips

Most surgeons use non absorbable sutures such as polypropylene or PTFE but there is some evidence from non-randomized studies that the use of non-penetrating nitinol vascular clips may improve the subsequent patency of AVFs(232, 233) although this was not confirmed by one small randomized study.(234) However, clips are not suitable for use in calcified vessels.

5.1.14. Other challenges

Vessel calcification may limit access options, particularly in diabetic patients, but an AV anastomosis can be performed to arteries with mild “egg-shell” calcification either using firm bulldog clamps or a tourniquet. Severe calcification makes performing the anastomosis difficult and the associated vessel rigidity may compromise maturation. Calcification and increased arterial wall thickness have been shown to significantly increase the primary failure rate of forearm AVFs(105) and calcification may also be a marker of poor prognosis.(235) Obese patients present difficulties in visualizing the veins so that preoperative DUS scanning is invaluable. When the vein is located deeper than 0.6cm from the skin surface it may be difficult to cannulate which is a possible cause of reduced patency(236) and either elevation or transposition either as a primary or secondary procedure may facilitate cannulation with patency rates similar to those of non-obese patients.(237-240) Liposuction over a guard has also been used successfully to elevate the vein draining an AVF to facilitate needling.(241, 242)

5.2. Perioperative assessment

Whatever form of AVF or AVG is employed, at the end of the operation there should be a palpable thrill or, at least, an audible bruit overlying the anastomosis or over the vein close to the anastomosis. The absence of a bruit has been found to be a good predictor of early AVF thrombosis and whilst duplex ultrasound measurements of end diastolic velocity were a slightly better predictor the difference in specificity and sensitivity was marginal.(243) If a thrill fails to appear after releasing the clamps on the vessels, application of a vasodilator such as papaverine may aid vasodilatation but if this is unsuccessful the anastomosis should be carefully checked for defects and an embolectomy catheter or a bougie passed. The presence of a strong pulse in the vein draining a fistula without a thrill or bruit usually indicates a downstream venous stenosis or occlusion. Intraoperative blood flow measurements can also identify fistulas at high risk of failure(244-247) but are relatively imprecise and probably have little use in day-to-day practice. Before leaving the operating room, the hand should be assessed for ischaemia including capillary return and, in the case of proximal fistulas, the radial pulse recorded.

5.3. Perioperative complications

Arteriovenous grafts or fistulas should be evaluated soon after their creation and then routinely examined during their lifespan either by means of physical examination to detect physical signs that suggest the presence of dysfunction (monitoring) or by periodic evaluation using tests involving special instrumentation (e.g. DUS) (surveillance). Access thrombosis, including early thrombosis within the first 30 days after creation, is the most frequent complication leading to failure of either autogenous or prosthetic AV access procedures.

Recommendation 25

After creation of a vascular access there should be a palpable thrill or a bruit in the region of the anastomosis. Class I, Level C(248)

5.3.1. Hemorrhage

Hemodialysed patients have an increased bleeding tendency with abnormal bleeding times despite normal coagulation studies and platelet counts.(248) Scheduling access procedures on the day between dialyses sessions decreases exposure to the heparin used to prevent clotting in the HD circuit.

Early post-operative hemorrhage may need rapid intervention for hemostasis while preserving the access function. Direct digital compression is required followed by surgical revision if the bleeding persists. Clinically significant hematomas remaining after the bleeding has stopped may require evacuation to reduce the risk of infection or skin necrosis.

Recommendation 26

Scheduling elective access procedures on a day between hemodialysis sessions should be considered to decrease the exposure of patients to the heparin used in dialysis. Class IIa, Level C, Ref (248)

5.3.2. Postoperative infection

VA site infection is an important cause of morbidity and mortality in patients on HD. The reported incidence of infections affecting the AV access sites ranges from 0.5-5% per year for autologous AVFs to 4-20% for prosthetic AVGs.(248) Peri-operative infections (within 30 days of creation) have a low incidence (0.8%) and account for only 6% of all access site infections.(155) They result from contamination during the operation and present as abscesses and wound infections. Autologous AVFs infections are usually localized and in the absence of abscess, pseudoaneurysm or hemorrhage may respond to appropriate antibiotics.(248) Whilst there is no published evidence on the duration of antibiotic therapy, 6 weeks treatment has been recommended by analogy to the treatment of endocarditis.(249, 250)

In contrast to late infections, early peri-operative synthetic graft infections involve the entire graft and total graft excision is required.(155, 248, 251, 252) When necessary, brachial artery ligation should be performed and is in most cases well tolerated.(253)

Patients who exhibit systemic signs of infection, bleeding, pseudoaneurysm or involvement of the anastomosis should have their grafts completely removed or the autologous fistulas ligated.(253)

Recommendation 27

In the absence of hemorrhage or pseudoaneurysm early peri-operative (<30 days) autogenous arteriovenous fistula treatment of infection with appropriate antibiotics should be considered . Class IIa, Level C, Ref (248)

Recommendation 28

Early peri-operative (<30 days) arteriovenous graft infection should be treated by total graft removal. Class I, Level C, Ref (155, 248, 251-253)

Recommendation 29

For early autologous arteriovenous fistula infection in the presence of systemic signs, bleeding and involvement of the anastomosis, fistula ligation should be performed. Class I, Level C, Ref (248)

5.3.3. Non-infected fluid collections

Seromas are occasional complications of prosthetic AVGs but are rare in AVFs. They may result from “sweating” through a ePTFE graft, which can be minimized by the avoidance of stretching.(225) The major concern regarding a seroma is whether it represents a low grade infection. Needle aspiration may be helpful diagnostically and may be curative. If a seroma persists, the access must be abandoned in favor of a new graft. Other seromas may resorb

spontaneously but surgical drainage with excision of the cavity wall or even graft replacement may be necessary.(248)

Lymphatic collections usually resolve spontaneously with or without the aid of repeated aspiration(248) but persistent lymphorrhea through a sinus carries a risk of infection, especially if a graft is involved. Vacuum assisted closure (VAC) devices have been used successfully for open wounds following VA procedures(254) and may aid closure if a lymph leak causes a significant open wound. However, it is probably unwise to directly apply them over vascular anastomoses or the vein draining an AVF as this might result in major hemorrhage from anastomotic disruption or erosion of the vessel.

5.3.4. Early onset of vascular access induced limb ischemia (See Chapter VII)

A wide spectrum of ischemic symptoms may complicate access creation. Four stages with similarities to Fontaine's classification for lower limb ischaemia in peripheral arterial disease have been described (see definitions). (255). Clinically significant limb-threatening ischaemia with rest pain (stage 3) or tissue loss (stage 4) occurs in 4-9% of proximal (brachial artery) access procedures.(248) Usually, the diagnosis of ischaemia can be easily made by the absence of a radial pulse, pallor or slow peripheral return of circulation after compression with digital pressures of <50 mm Hg and a digit/brachial index of <0.6 .(255) These changes are reversed by compression of the fistula.

Although more than 80% of steal related limb-threatening ischaemia is caused by discordant vascular resistance, 20% results from a proximal inflow stenosis. A arteriography may be helpful before embarking on surgical correction in equivocal cases.(256) In half of patients with steal, limb threatening VAILI develops within month of access creation, often appearing immediately after surgery.(257) Patients should be closely observed during the first 24 postoperative hours following proximal VA creation and close observation is probably unnecessary beyond . Monitoring for steal is not recommended beyond the first postoperative month in patients with AVGs, while lifelong monitoring should be performed in

proximal AVFs as these may present a delayed onset of steal symptoms after maturation and late vein dilatation.(258)

Early onset limb threatening ischaemia should be treated by immediate surgical correction of steal. Ligation is the simplest solution, which requires abandonment of the access site but is advisable for severe symptoms of early onset and should be performed urgently to prevent tissue loss and permanent neurological damage of ischemic monomelic neuropathy (IMN).(248) Some authors have suggested the DRIL procedure but this may not be as successful in early onset as for late onset steal.(259)

IMN may also rarely occur in the absence of steal, probably as a result of transient ischaemia during surgery. It is characterized by pain with sensory and/or motor deficit an all three major nerves in the affected limb out of proportion to any residual ischaemia. It can be confirmed by nerve conduction studies. It requires prompt ligation of the access to prevent continued pain and may progress to a useless clawed hand. Treatment in the chronic phase is often unsatisfactory and relies on analgesics, antidepressants and anticonvulsants. (248)

Recommendation 30

For early limb-threatening vascular access induced ischemia and all cases of early ischemic monomelic neuropathy in the absence of steal the access should be urgently ligated. Class I, Level C, Ref (248, 259, 260)

5.3.5. Early thrombosis

The most frequent complication in all access types is early thrombosis which is defined as occurring within 30 days of access creation.(9) If the access is to be preserved, treatment within 7 days is advisable. The longer the intervention is delayed the more likely the thrombus is to propagate and become fixed to the vessel wall, making thrombectomy more

difficult and less durable because of damage to the endothelium. The thrombus can be removed either surgically using a Fogarty balloon catheter or by endovascular means using chemical or mechanical thrombolysis, or a combination of these. Thrombectomy alone is insufficient unless the responsible factor is transient, such as an episode of hypotension and any treatment of any underlying stenosis is required.

Early access thrombosis is usually attributed to technical errors during surgery and is best treated by surgical revision rather than endovascular intervention.(261) However, in a series of 20 early AVG thromboses only one patient was found to have technical problems and most grafts thrombosed because of hypotension, hypercoagulable states or previously undetected lesions in the proximal draining vein or central veins.(262)

Endovascular treatment of early postoperative thrombosed grafts with thrombolysis and treatment of any underlying stenosis with PTA/stent, has been shown to give good results but should be delayed for at least 7 days after the access creation to allow tissue incorporation to prevent puncture site bleeding.(262) In another series of 23 early graft thrombosis, reported poor outcomes following percutaneous declotting.(263) During surgical thrombectomy, intra-operative angiography and either PTA or surgical revision of any underlying stenosis should be performed.(262)

Recommendation 31

If the access is to be salvaged after early thrombosis thrombectomy should be performed as soon as possible, either by surgical or endovascular means. Class I, Level C, Ref (261)

Recommendation 32

Access salvage after thrombosis within 7 days of access creation should be accomplished. Class I, Level C, Ref (262)

5.4. Postoperative care

It is wise to keep the patient and the extremity bearing the newly formed AVF warm to promote vasodilatation although there is no evidence to support this. The application of transdermal glyceryl trinitrate to RCAVFs during the immediate postoperative period caused significant vasodilatation and increased blood flow in a small randomized trial but, to date, there is no evidence that this increases patency rates.(264) Patients should be instructed to check the function of their new AVF, by palpating the thrill or, in its absence, by auscultation of the bruit. They should be advised to report urgently to the VA nurse or medical team if the thrill or bruit disappears and must have easy access to urgent medical help in the event of bleeding or signs of infection.

5.5. Training of surgeons to perform vascular access

Increasing AVF creation rates over AVGs is an indisputable priority. Training of VA surgeons seems to be the key predictor of whether priority is given to the placement of AVFs rather than AVGs. Surgeons who had performed more AVFs and fewer AVGs during training subsequently created more AVFs and fewer AVGs during their specialist practice.(47) Greater emphasis on VA surgery during training also was associated with higher odds of a patient receiving a AVF versus AVG. Surgeons who had created at least 25 AVFs during training had a significantly lower rates of AVF failures than those placed by surgeons who had created fewer than 25 with a relative risk of 0.66. (47, 265)

There is conflicting evidence on whether the grade of the operating surgeon affects access outcomes. Two retrospective studies have shown that well supervised trainees do as well as specialists (266, 267) whilst another retrospective study concluded that trainees produced poorer outcomes. (268) The operating surgeon, seems to be a significant determinant for the AVF outcome(46), but in a prospective non-randomized study unsupervised vascular

trainees performed AVFs equally effectively as consultants(266, 269) so that AVFs can provide good training opportunities without detriment to patient care.

Recommendation 33

Vascular access training programs must supervise adequate numbers of autologous fistulas for each trainee (> 25). Class I Level C, Ref (46-48, 265-270)

Chapter VI

Surveillance of vascular access

6.1. Access maturation and care

6.1.1. Concept

When a fistula is created, a continuous flow from the artery to the vein initiates a cascade of changes, altering wall structure, shear stress, and rapidly increasing flow during first 24 hours, achieving most of the increase in flow and vein diameter up to 8 weeks after access placement.(123, 181) AVFs are usually not readily usable after creation, but these changes lead the fistula to become suitable for cannulation over time, a process known as maturation.(249)

A fistula is considered mature when it is thought to be appropriate for cannulation with minimal complications, and to deliver the prescribed blood flow throughout the HD procedure. It is established by experienced staff physical examination of the VA and/or imaging (DUS), before access cannulation, that predicts successful use and flow delivery during HD. It should happen preferably after 4-6 weeks of AVF or 2-4 weeks of standard AVG creation.(123, 249, 271, 272)

Cannulation should be considered only in mature VA because of the risk of puncture complications, VA failure insufficient HD quality. When is the VA cannulated successfully with two needles over a period of at least 6 HD sessions during a 30-day period, and delivering the prescribed blood flow throughout the HD procedure (at least 350 ml/min)(273), the access is finally considered adequate for HD. An VA that is currently being used for VA during HD sessions is considered a functional VA.

6.1.2. Maturation of arteriovenous fistula?

6.1.2.1. Physical assessment and other diagnostic methods

Maturation can be established by physical examination of both the venous conduit and its flow. It is usually assessed by the presence of an adequate venous diameter with or without a proximal tourniquet in place (to permit safe landmark recognition and cannulation), a soft easily compressible vein, a continuous audible bruit (a low pitched continuous systolic and diastolic audible bruit), a palpable thrill near the anastomosis extending along the vein for a varying distance, with an adequate length and superficial enough to be punctured with two needles.(181, 274) Experienced staff have shown an excellent ability to predict eventual fistula maturity. (123, 249) Causes of non-maturation include any factors that may cause difficulty in cannulation and flow delivery (thrombosis, arterial or venous stenosis, small diameter or deep veins, presence of accessory veins).

Postoperative ultrasound examination between the first 6-8 weeks and 2-4 months(123) after fistula creation is helpful in setting maturation. In general, a draining vein diameter of less than 4mm and fistula flow of less than 500 mL/min indicates a fistula that is unlikely to mature.(123, 271, 272) Some groups recommend the rule of 6's to define maturation (at least 6mm of vein diameter and 600 ml/min flow, and less than 6mm vein depth) (249), which is probably quite conservative.

6.1.2.2. Time to maturation

An access is cannulated when it is considered mature. However, the optimal delay to use VA since its creation, whether autologous or prosthetic, is not unanimously agreed. Premature needling may predispose to access failure (because of thrombosis or extrinsic compression by hematoma following damage to the thin wall of the freshly arterialized vein), and longer maturation time (>30 days) appears to be associated with lower risk of AVF failure. (185, 275, 276) However, early cannulation can reduce the need for a temporary catheter and its complications. Furthermore, significant differences between groups and countries have been observed: AVFs were first cannulated <1 month after creation in 74% of Japanese facilities, 50% of European and only 2% of US. (277) Early cannulations were not associated with

increased risk of VA failure, probably also related to smaller needles and lower flows used in Japanese facilities.

This waiting time is feasible only when there is no impending need for the commencement of HD, which is frequently not the case. Thus, clinicians may be able to select appropriate patients for early fistula cannulation depending on maturation criteria and the time after fistula creation, but also based on the need or the risk of complications of other HD methods.

If AVF maturation has not occurred by 6 weeks, causes of non-maturation should be considered and additional investigations should be performed in order to achieve prompt diagnosis and treatment.(123, 271, 272, 278)

Secondary interventions in previously matured fistulas (i.e. proximal reanastomosis, thrombectomies or endovascular procedures), or proximal fistulas in patients with previous distal matured fistulas, may need no maturation period if the veins are already mature.

Recommendation 34

Arteriovenous fistulas should be considered for cannulation after 4-6 weeks of creation; , and standard arteriovenous grafts after 2 - 4 weeks. Class IIa, Level B, Ref. (132, 133, 135, 185, 249, 275-277, 279, 280)

Recommendation 35

If an arteriovenous fistula fails to mature by 6 weeks, additional investigations should be considered in order to achieve prompt diagnosis and treatment. Class IIa, Level C, Ref. (185, 271, 272, 275-277, 279)

Recommendation 36

Arteriovenous fistula cannulation before 2 weeks should not be considered. Class III, Level B, Ref.(185, 275, 277, 279)

Recommendation 37

Arteriovenous fistula cannulation between 2 and 4 weeks after creation should be performed in selected patients under close supervision. Class IIa, Level B, Ref. (185, 275, 276)

6.1.3. Time to cannulation of the arteriovenous graft

Because of its stiffer wall, AVG usually show weaker palpable thrill over the entire graft than AVFs.(249) In grafts, maturation is based on the time needed for tissue-to-graft incorporation and for tissue swelling to decrease after graft implantation, rather than flow increase over time (because the flow is high from the day of surgery with minimal changes over time).(281) It is usually defined as 2 to 4 weeks (followed by 62% of USA and 61% of European facilities).(277) There was no significant difference in the risk of graft failure between those cannulated early in comparison to those with later cannulation.(277, 280) If maturation takes more time, causes of non-maturation that are unlikely to improve over time should be studied (e.g. excessively deep tunneling or graft thrombosis).

Some grafts allow for early cannulation within 24-72 hours without major complications (either polyurethane grafts, or multilayer ePTFE grafts allowing self-sealing), avoiding catheters in patients that need early HD and that do not have suitable veins for a fistula. However, this type of graft confers no additional benefit other than early cannulation(223, 282) and mid-term patency outcomes are under investigation.(220)

6.1.4. Access care

After access surgery, patients should receive information about wound healing, warning signs (infection, symptoms of ischemic steal syndrome, bleeding and other postoperative complications), avoiding fistula compression or injuries, and encouraging an exercise program.(149, 283, 284)

Patients should be instructed to check the function of their new AVF (self-examination), by palpating the thrill. They should be advised to report urgently to the VA nurse or medical team if the thrill disappears and must have easy access to urgent medical help in the event of persistent bleeding in spite of manual compression, or signs of infection.(181, 249)

In patients undergoing HD, experienced staff should examine the fistula in each HD session (before fluid removal).(249) Patients in pre-dialysis therapy should be taught how to perform self-examination, and at a minimum they must be physically examined by experienced staff following a systematic approach 4 to 6 weeks postoperatively.(285)

6.1.5. Assessment and treatment of maturation failure

Non-maturation rates differ between groups, ranging from just under 10% in BCAVFs to up to 33%, or even more, in RCAFVs(26); women, older patients, distal placements and accesses with smaller artery and vein are risk factors for failure to mature.(272, 286, 287) Additional investigations such as DUS or angiography are indicated if physical examination by experienced staff determines failure to mature after 6 weeks of AVF creation or poor prognostic signs (faint or absent thrill, complete access collapse proximally, discontinuous bruit, high pitch continuous systolic audible bruit, pulsatile AVF, low diameter or poorly defined vein, excessive depth, large accessory/collateral veins).(123, 278, 288)

Non-matured fistulas frequently have one or more potentially remediable problems, and up to 80% can be salvaged after surgical or endovascular correction(289, 290), although thereafter cumulative survival rates are decreased and require more secondary interventions to maintain patency.(291) The most common causes of non-maturation are venous, arterial or anastomotic stenosis, competing veins or large patent branches, and excessive depth from the skin.(57) According to the cause, open or endovascular repair can be performed, although in general no significant differences have been found between to two modalities.(290) (see chapter 7: Clinical Outcomes).

Problem-specific salvage procedures increase the proportion of fistulas that are mature and usable for HD(288), and if a fistula fails to mature, the patient should be referred immediately back to the surgeon or the interventionist for prompt evaluation and intervention.(249, 292)

6.2. Measures to improve maturation

Apart from time to wait after VA creation, pre and intraoperative treatments, or additional postoperative surgical or endovascular procedures (i.e. side branch ligation, superficialization, treatment of stenotic lesions and others), other postoperative treatments can improve fistula maturation and long-term patency:

6.2.1. Exercise

After AVF creation, vein diameters immediately increase following arm exercise.(283) Compared to non-exercise, hand-arm exercise programs cause significant outflow vein dilatation and increase VA flow. In two randomized clinical trials structured hand exercise programs significantly increased clinical maturation after AVF creation, mainly in distal AVs..(149, 283, 293) Therefore patients should be encouraged to follow a hand-arm exercise program after AVF creation.

Recommendation 38

Structured postoperative hand exercise training can increase arteriovenous fistula maturation should be considered . Class IIa, Level B, Ref. (132, 133, 135, 149, 283, 284, 293)

6.2.2. Antiplatelets and anticoagulation

The role of antiplatelet therapy improving VA maturation or suitability for cannulation is uncertain: in recent systematic review and meta-analysis, antiplatelet treatment was found to significantly reduce by half early AVF thrombosis and loss of patency.(156-158). However,

antiplatelets had no significant effect on AVF primary patency, AVF maturation and did not improve VA suitability for HD.(157, 294)

A preventive role of antiplatelet therapy decreasing cardiovascular mortality in ESRD patients had been proposed.(295) However, even if antiplatelet treatment has been related to a decrease in myocardial infarction (RR 0.87), all-cause mortality, cardiovascular mortality and stroke remains similar, and it was related to an increase in major and minor bleeding (RR 1.33 and 1.49)(157, 158, 294, 296, 297). Thus, the real benefit of antiplatelet treatment in improving access suitability or cardiovascular mortality, specifically in ESRD patients who do not have clinically evident occlusive cardiovascular disease, is doubtful.

Dual therapy (aspirin plus clopidogrel) significantly increased the risk of bleeding, suggesting that this combination may be hazardous.(298)

Anticoagulation strategy using LMWH and oral anticoagulants has not been extensively evaluated in HD patients. There is only one randomized study using low-dose warfarin for the prevention of AVG failure which found of no benefit,(299) while in DOPPS such treatment was associated with worse graft patency rates.(85) Additionally, in a systematic review increased bleeding events were associated with warfarin use compared with placebo in patients with fistulae or grafts.(156) Regarding LMWH thrombo-prophylaxis, there is only one comparative study with historical controls in a pediatric population reporting a decrease in early fistulae failure in the treatment group.(300)

Recommendation 39

Antiplatelet treatment cannot generally be recommended to improve vascular access suitability for hemodialysis or avoid overall mortality in end stage renal disease patients.
Class III, Level A, Ref. (157, 158, 294, 296, 297)

Recommendation 340

Long-term anticoagulation should not be used to prolong vascular access patency in

hemodialysis patients. Class III, Level A, Ref. (85, 132, 133, 135, 156, 299, 300)
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6.2.3. Other treatment options

Calcium channel blockers and angiotensin-converting enzyme inhibitors have been associated with improved primary graft and secondary fistula patency respectively in a single observational study, but more conclusive data is lacking.(85)

There are insufficient data available to adequately assess the efficacy of omega-3 fatty acids (fish oil) improving access function or maturation.(301, 302) In a randomized controlled trial among patients with new VA grafts, daily fish oil ingestion did not decrease the proportion of grafts with loss of native patency within 12 months, but it improved graft patency, rate of thrombosis, and interventions. (304) Beside, there is one large ongoing randomized trial designed to test whether fish oil plus aspirin can indeed improve the patency of VA. (303) Statins have pleiotropic beneficial actions besides lipid lowering. Two non-randomized studies report contradictory results regarding their effects on VA patency rates.(304, 305) Until recently, there is no direct evidence of an effect of statins on AV fistulae or AV graft patency rates.

As previously described, most recommendations are based on clinical experience, but interventions that clearly improve VA maturation and suitability for HD are needed.(158)

6.3. Cannulation

The maintenance of the VA not only depends on the quality of the blood vessels, and the surgical technique used, but also on the way in which the VA is cannulated. After creation of the initial VA, preferably an autogenous AVF, the correct needling technique has a favorable influence on fistula lifespan. Nurses play a pivotal role in the care of VA: they see the patient during every HD session, perform cannulation and assess VA function.(43) VA cannulation is a basic but essential part of the HD treatment and requires skill from the nurse, or patient if self-cannulating. A chronic HD patient needs at least 312 needle insertions per year (6x52). It

is reasonable to assume that complications caused by cannulation, such as hematoma, infection and pseudoaneurysm formation can have great consequences in terms of suboptimal HD, the need for extra needle insertions, patient discomfort, interventions and even loss of the access.

Frequent access complications, particularly with AVGs, have led to the development of VA monitoring protocols(306) whose goal is to identify access stenosis and enable intervention prior to thrombosis; thereby, maximizing access longevity and minimizing morbidity.(249)

6.3.1. Access care before cannulation

6.3.1.1. Skin preparation

Proper preparation of the access sites using strict aseptic technique can eliminate contamination and/or access infection and should be used for all cannulation procedures.(249) VA related infections are a leading cause of morbidity and mortality in HD patients. AVGs and CVCs are associated with an increased risk of infection when compared with AVF.(307) Studies have suggested that the buttonhole cannulation technique is associated with an increased risk of access-related infections.(308-311)

It has been shown that HD patients are more frequent nasal and skin carriers of staphylococcus aureus than the general population.(312) For this reason, meticulous skin preparation prior to any cannulation is of critical importance.(313)

To minimize infections, facilities should have a procedural policy for patient access preparation.(314) Dialysis nurses should clean the skin with a facility-approved antimicrobial preparation. There are several such cleansing solutions available for VA disinfection each one requiring a different length of application and time to be effective (314). The dialysis staff should wear clean gloves for cannulation.(249)

Circular cleansing is generally preferred over the east-west technique although there is no hard evidence to support this at present.(249)

6.3.1.2. Anaesthesia

Pain related to cannulation is a significant concern for some patients. Anaesthetics available for needle insertions include topical creams such as those containing both lidocaine 2.5% and prilocaine 2.5%, intradermal lidocaine injection, and coolant sprays which cause reduced pain sensation by rapid skin cooling on evaporation.

It has been shown that depth of anaesthesia with topical anaesthetic creams depends on the contact time: In order to reach a maximal depth of 3 mm, the topical anaesthetic cream has to remain on the skin for 60 minutes and to reach a depth of 5 mm the cream has to be on the skin for 120 minutes.(315) Side effects are rare but include redness/rashes or whitening at the site of the application.

6.3.1.3. Precannulation examination

VA stenosis is the most common cause of access dysfunction. Monitoring by physical examination to detect the physical signs of dysfunction, before any cannulation, is of utmost importance. Monitoring should consist of a full physical examination on the VA prior to every HD session including inspection, palpation and auscultation.(314) Inspection may reveal swelling, signs of infection (redness, discharge, oedema), aneurysms, haematoma, the color of the hand and stenosis. Palpation should reveal a characteristic thrill. A change in the strength of the pulse over a short segment may indicate a stenosis, while a pulsatile AVF indicates the presence of a downstream or distal stenosis. Post-stenotic collapse of the vein on elevation of the arm can demonstrate the haemodynamic relevance of a stenosis. The access should have a bruit on auscultation which will be high-pitched over a stenosis.(43) Monitoring should also include a review of regular routine laboratory, including HD adequacy (urea reduction ratio or Kt/V), and difficulties in cannulation or achieving hemostasis after needle withdrawal, documented recirculation, and other clinical clues.(316) Observed changes over time should be documented and further investigated by means of vascular imaging techniques like DUS, DSA or MRA. Physical examination for the detection of stenosis has a positive predictive value of 70% to 80% in AVGs and a specificity of 93% in AVFs.(278, 317-321)

6.3.2. Cannulation techniques

6.3.2.1. Needle selection

It is important to choose the appropriate needle according to the desired blood pump speed and the available access flow rate in the VA in order to optimize HD efficiency.

Needle selection is especially critical for the initial cannulation. One method used to select the appropriate needle size is a visual and tactile examination. This examination allows the person performing the cannulation to determine which needle gauge would be most appropriate, based on the size of the vessels of the fistula. If the needle is larger than the diameter of the vein with the tourniquet applied, it may cause infiltration with cannulation. The needle size should be equal to or smaller than that of the vein (without tourniquet). It is also important to match needle gauge to the blood flow rate. For initial cannulation attempts the smallest needle available, usually a 17 G, typically is used. If the arterial pressure falls below 200 to 250 mmHg, and the venous pressure is higher than 250 mmHg, the needle size should be increased (i.e., a smaller gauge number should be used). The arterial needle should always have a back eye (an oval hole/opening at the back site of the needle) to maximize the flow from the access and reduce the need for rotation and flipping the needle.(249)

6.3.2.2. Ultrasound-assisted cannulation

Cannulation-related complications are especially common in patients with a new VA, which may result in the use of CVC or single needle HD, especially in native AVFs.(322, 323)

DUS guided cannulation of fistulas might improve the cannulation rate of more difficult fistulas, potentially reduces the time required to commence HD and the number of local complications of cannulation but randomised controlled trials of DUS guided cannulation versus blind cannulation are needed.(324, 325). Ongoing education and training of the dialysis staff towards theoretical knowledge and cannulation skills, especially for cannulation of new AVFs is essential.(322)

After creation of an AVG most patients experience significant tissue swelling as a result of tunnelling so that palpation of the graft is difficult for the cannulator and painful for the patient. Therefore, grafts generally should not be cannulated for at least 2 weeks after placement and only after the swelling has subsided and palpation along the course of the graft can be performed. Early cannulation grafts should, if possible, be left for at least 24 hours after placement and until after swelling has subsided so that palpation of the course of the AVG can be performed.(249)

Three cannulation methods

There are three methods for cannulation of the VA; the rope-ladder technique (rotation of cannulation sites), the area technique and the buttonhole technique (constant site cannulation).

6.3.2.3. Rope-ladder technique

The rope-ladder technique uses the entire length of the cannulation segment for cannulation: every HD session, two new puncture sites are created, with approximately 5 cm between the tips of the arterial and venous needles, and at least 3 cm from the anastomosis, avoiding the previous sites. The rope-ladder technique results in a moderate vessel dilatation over a long vein segment.(326)

The venous needle is placed in the direction of the blood flow (antegrade). Arterial needle placement can be antegrade or retrograde (against the direction of the blood flow). The direction of the arterial needle will not influence the risk of recirculation as long as the access blood flow is greater than the blood pump flow.(249, 327-330) Bevel position and flipping of needles is a controversial issue. Both bevel up and bevel down cannulation are acceptable until further studies can demonstrate risk/benefits of either technique.(314, 331)

Based on assessment of the VA, the dialysis nurse chooses the unique angle of insertion for the HD needle. Generally, the angle of insertion for AVF is 25 degrees, and for AVG 45 degrees.(249) Cannulation of AVG is different than AVF; grafts are tougher than autogenous

vessels. Cannulation related complications are more often seen in autogenous AVFs.(322)

The few publications concerning access handling and the outcome of specific cannulation techniques advise the rope-ladder technique for the cannulation of AVGs, to avoid AVG disintegration and the formation of pseudo-aneurysms.(43, 323)

6.3.2.4. Area technique

With the area cannulation technique there will be repeated cannulation in the same area of the VA. This may lead to aneurysmal dilatation of the puncture areas with subsequent stenoses in adjacent regions.(326) Also the overlying skin becomes thinner, which leads to longer bleeding times after the needles are removed. This technique is less widely used, and is no longer recommended.(332)

6.3.2.5. Buttonhole technique

Another cannulation technique is the buttonhole (constant-site) technique.(333) The buttonhole technique is not used for AVGs.

The buttonhole technique requires different skills of the dialysis nurse than the rope-ladder technique as the AVF needs to be repeatedly cannulated at exactly the same site, using the same insertion angle and the same depth of penetration every time.(333, 334) In approximately 6 to 10 sessions a tissue tunnel track is formed with sharp needles, enabling the subsequent use of blunt needles for cannulation. Ideally, a single cannulator should cannulate the fistula until an established track is created to reduce the risk of track malformation. The cannulation sites should be selected carefully in an area without aneurysms and with a minimum of 5 cm between the tips of the needles. After a good puncture route is established, the fistula can be punctured with dull edged needles, to prevent damaging the tissue tunnel and the formation of faulty tracks.(335) Following transition to blunt needles, a single cannulator is no longer required. Subsequent cannulators should only use blunt needles and must follow the direction and angle of the developed track.(336, 337)

Observational studies showed several benefits of the buttonhole cannulation with reduced complication rates: fewer infiltration rates resulting in a reduced incidence of haematoma formation(308, 336, 338), fewer aneurysms(308, 336, 338), improved haemostasis times(338, 339) and less pain during cannulation.(334, 340) Various studies have also reported that the buttonhole technique contributes to the cannulation ease for self-cannulating patients(336, 341, 342), which extends the life expectancy of the AVF.(343-345) Recently performed randomized trials regarding the potential benefits of the buttonhole technique demonstrated also reduction of aneurysms(346) and less hematoma(346, 347), but did not find difference in pain.(346-348)

Studies have reported an increased risk of infection in patients cannulated with the buttonhole technique.(308-311, 336, 337) These infections ranged from minor skin infections at the access site to bacteremia sepsis. Inappropriate application of the disinfection protocol with incomplete scab removal by nursing staff or self-cannulating patients was highlighted as a likely cause of increased infection rates.(308, 311) Staff re-education regarding cleansing technique and scab removal resulted in a reduction of infection rates.(310, 349)

Correct needle placement with approximately 2 mm of the needle exposed, can prevent the development of large scab formation in the buttonhole sites.(334) The best demonstrated practice, touch cannulation technique(350) decreases the ability of staff members to manipulate needles, resulting in better cannulation success. Antimicrobial prophylaxis has been studied in patients using the buttonhole technique with favorable results.(349, 351)

Currently, the available literature does not recommend the routine use of the buttonhole method in all AVFs. However, the buttonhole cannulation technique may be especially appropriate for patients with a short cannulation segment.

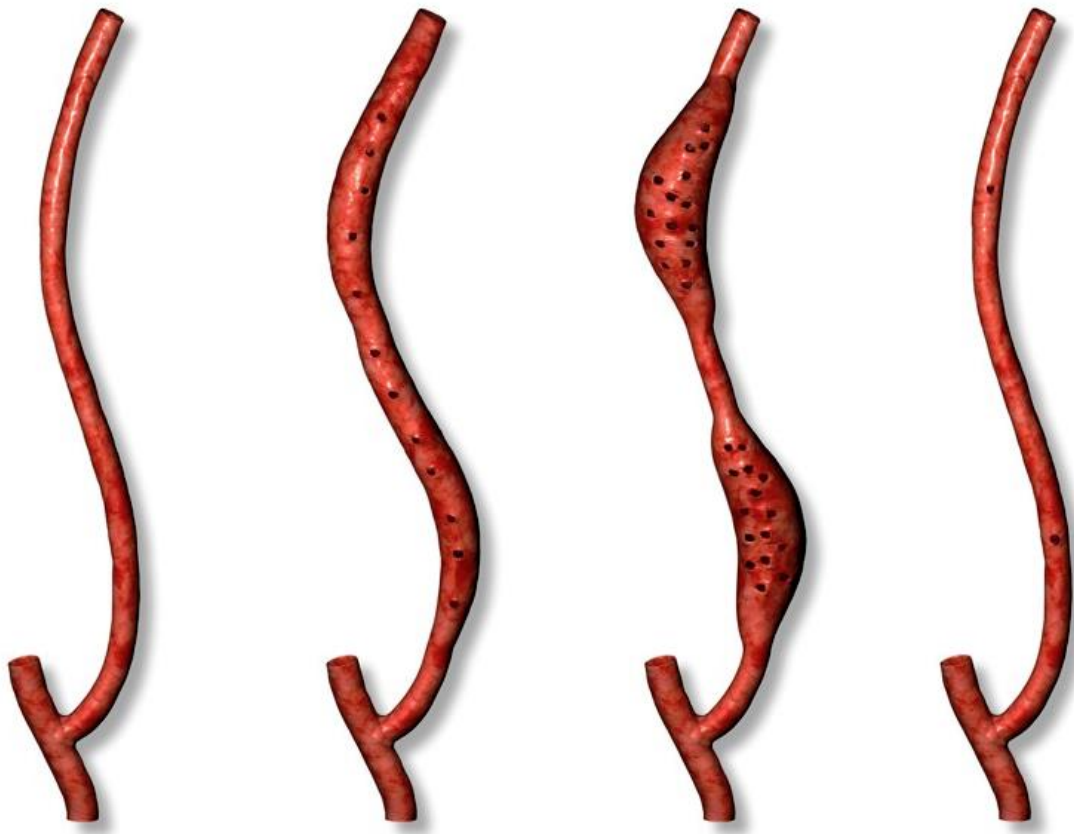


Fig. 5: VA cannulation techniques: A: AV graft, B: rope-ladder technique, C: area technique, D: buttonhole technique

Several studies have highlighted the importance of staff experience on VA outcomes. The DOPPS data found that each 20% increase in the number of experienced staff nurses (nurses who had worked in HD >3 years) was associated with an 11% reduction in AVF failure ($RR=0.89$; $P<0.005$) and 8% reduction in AVG failure ($RR=0.92$; $P<0.001$). Careful consideration of individual AVF and patient characteristics, patient preference and the primary cannulator is required when choosing the most appropriate cannulation method. Cannulator inexperience may result in access complications regardless of the technique adopted.(352) Therefore, successful access cannulation requires a high level of awareness and skills of the dialysis nurse, frequent monitoring, and a continued evaluation and education of the needling technique.(308)

6.3.3. Access care after needle withdrawal

The technique of needle removal is as important as that of cannulation, to protect the access from damage and to facilitate proper hemostasis. The needle should be removed at approximately the same angle as it was inserted. After the needle is removed, gentle direct pressure should be applied to the needle exit sites of both the skin and graft or vessel wall, using a two digit technique over a hemostatic dressing.(43, 353) Pressure to the puncture site should not be applied until the needle has been completely removed, to prevent damage of the VA.(43, 314) In general, prosthetic grafts require a longer time to achieve hemostasis than AVFs. Whilst compressing, it is important to ensure a flow can be felt in the access.(353)

The use of clamps to assist hemostasis should be discouraged. When clamps are used, they should only be applied to a mature access with an adequate flow, monitored closely, and should be used only if flow can still be palpated in the AVF or AVG while the clamp is in place. A dressing should be applied to the cannulation sites using any number of options (with or without a hemostatic agent), but should not encircle the limb to avoid constriction of blood flow to the access. Prior to the patient leaving the unit, the quality of the bruit and thrill should be assessed and documented.

Difficulties in cannulation or achieving hemostasis after needle withdrawal can be a sign of venous outflow stenosis in a patient with normal bleeding times. If prolonged hemostasis is ongoing, the anticoagulation should be reassessed, dynamic venous pressure readings should be reviewed, and access flow studies performed to rule out stenosis as a cause.(43)

Recommendation 41

Strict aseptic technique should be used for all vascular access cannulations. Class I, Level C, Ref. (43, 132, 133, 135, 249, 312)

Recommendation 42

Physical examination of the vascular access prior to any cannulation is recommended.

Class I, Level C, Ref. (43, 278, 316-321)

Recommendation 43

In patients with a short cannulation segment the use of the buttonhole technique should be considered over other techniques.

Class IIa, Level C, Ref. (43, 249, 326, 333)

Recommendation 44

The rope ladder technique should be used for cannulation of arteriovenous grafts. Class I, Level C, Ref. (43, 328)

6.4. Access monitoring and surveillance**6.4.1. Concept**

VA function and patency are essential for optimal management of HD patients. Low access flow and loss of patency limit HD delivery, extend treatment times, and may result in under-dialysis that leads to increased morbidity and mortality.(354) In long-term AV accesses, especially AVG, thrombosis is the leading cause of loss of VA patency and increases health care expenditure.(355, 356) VA related complications account for 15% to 20% of hospitalizations among patients undergoing HD.(354, 357, 358)

The basic concept for VA monitoring and surveillance is that stenoses develop over variable intervals in the great majority of VAs and, if detected and corrected, under-dialysis can be minimized or avoided (dialysis dose protection) and the rate of thrombosis can be reduced. Whether prospective monitoring and surveillance can prolong access survival currently is

unproven. A number of monitoring and surveillance methods are available: sequential access flow, sequential dynamic or static pressures, recirculation measurements, and physical examination.(359)

A multidisciplinary team should be formed at each HD center(270, 360) with a VA team coordinator working proactively to ensure the patient is receiving an adequate HD dose by maintaining access function and patency. (270, 361)

6.4.2. Monitoring

Monitoring is the examination and evaluation of the VA to diagnose access dysfunction using physical examination, usually within the HD unit, in order to detect the presence of dysfunction and correctable lesions before access loss.

6.4.2.1. Physical examination

Physical examination can be used as a monitoring tool to exclude low flows associated with impending fistula and graft failures. There are 3 components to the access examination: inspection, palpation, and auscultation.(362, 363)

A simple inspection can reveal the presence of swelling, ischemic fingers, fingertip wounds like paronychia, aneurysms, rich collateral veins. The detection and referral of patients with a non-healing crust over the puncture site can save lives. A strong pulse and weak thrill on the vein central to the anastomosis indicates a draining vein stenosis. A fistula that does not at least partially collapse with arm elevation is likely to have an outflow stenosis. Strictures can be palpated and the intensity and character of the bruits can suggest the location of stenosis. In AVGs, the direction of flow is easily detected using a simple compression maneuver on the middle segment of the graft, the pulsating part indicates the arterial side and the non-pulsating the venous side, thus avoiding inadvertent recirculation by reverse needle insertion. A local intensification of bruit over the graft or the venous anastomosis compared to the adjacent segment suggests a stricture or stenosis.(363, 364)

Monitoring by physical examination is cost-effective and a proven method to detect access abnormalities.(318, 319, 321, 365, 366) Unfortunately, nephrologists and dialysis staff generally have limited knowledge of access anatomy and function, and regular physical examination of accesses is generally not carried out in HD units. This trend should be reversed by emphasizing proper VA training and clinical assessment in HD units.(285, 363, 367) Clinical monitoring appears to provide equivalent benefit in terms of VA survival in comparison to surveillance programs when coupled with preemptive corrective intervention.(129, 368)

Recommendation 45

It is recommended to perform vascular access monitoring by flow measurement of arteriovenous grafts monthly and arteriovenous fistulas every 3 months. Class I, Level B, Ref. (43, 56, 61, 249, 369-371)

Recommendation 46

Routine physical examination and clinical assessment is recommended for vascular access surveillance and maintenance. Class I, Level B, Ref (285, 318, 319, 321, 363, 365-367)

6.4.3. Surveillance

Surveillance is the periodic examination and evaluation of the VA by using diagnostic tests that may involve special instrumentation to diagnose access dysfunction. It can be done during or outside HD sessions, periodically to diagnose access dysfunction, or when monitoring indicates access dysfunction. The aim of surveillance is the detection of correctable lesions that may necessitate preemptive intervention to prevent access loss. Some diagnostic imaging modalities can also be used to treat the cause of the VA dysfunction.

6.4.3.1. Surveillance during hemodialysis

6.4.3.1.1. Flow measurement methods

VA blood flow can be measured indirectly by using indicator dilution techniques, or directly by using either DUS or MRA.(147)

6.4.3.1.1.1. Indirect flow measurement

The ultrasound dilution technique (UDT) is the most well-validated method for indirectly measuring access blood flow(372-375).(376, 377) In this technique, an indicator (saline) is infused distally into the VA after line reversal. Ultrasonic sensors measure changes in the protein concentration producing dilution curves used for the calculation of Q_a . Several factors have been identified that directly influence the accuracy of the measurements.(375, 378) Firstly, thorough mixing of the indicator is required. Secondly, as a result of cardiopulmonary recirculation (CPR), the second pass of the indicator will produce errors if it is incorporated into the measurement. CPR increases as access blood flow (Q_a) increases ($CPR = Q_a/CO$) and if incorporated, will cause an underestimation of the true Q_a value. Thirdly, the reversal of the blood lines that is required to perform the measurement will also influence the access blood flow result.

Fourthly, blood pump flow delivered to the dialyzer (Q_b) must be measured accurately as readings from the blood pump have been shown to overestimate delivered Q_b by 10% to 20%.(379)

6.4.3.1.1.2. Direct flow measurement

DUS measures blood flow velocity and in order to determine blood flow, cross-sectional area needs to be measured. The estimated flow can be inaccurate due to operator dependent determination of the blood velocity, and may be subject to error in estimation of the cross sectional area and the Doppler angle.(379-383) Advances in technology have made newly designed instruments more accurate and reproducible in measuring flow. (281, 384) The most popular method of flow measurement is calculation of the flow in the proximal brachial

artery and subtracting the flow in the contralateral brachial artery which is usually between 40-150 ml per minute.(385) This technique is supported by most DUS machines using automated multiplication of the time averaged mean velocity in the cross sectional area. VA flow can also be measured by MRA. However, apart from the danger of nephrogenic systemic fibrosis/fibrosing dermopathy, as this technique is expensive and cannot be performed during HD it is impractical as a screening tool.

6.4.3.1.2. Access flow and pressure surveillance

After their introduction, AVGs suffered recurrent thrombosis due to venous stenosis, necessitating frequent intervention. Dynamic and static dialysis venous pressure (VP) measurements combined with preemptive PTA yielded large reductions in thrombosis rates and replacement of VAs.(386, 387) These reports led the NKF-KDOQI guidelines to recommend that grafts and native arteriovenous fistulae undergo routine surveillance for stenosis with preemptive correction of the stenosis.(388)

The rationale for surveillance is based on the hypothesis that progressive stenosis is detected before thrombosis and access loss and a corrective procedure such as PTA can maintain patency of the VA. Non-randomized or observational studies are biased toward finding a treatment benefit.(389) For example, the influence of Qa on the relative risk of thrombosis was used to justify surveillance.(370, 390, 391) Although a low Qa is associated with an increased risk of thrombosis, this association does not have adequate accuracy in predicting thrombosis. In contrast, Qa and VP surveillances were found to be inaccurate predictors of graft thrombosis and instead of preventing thrombosis yielded many unnecessary intervention procedures.(392-396) Moreover, PTA induces a mechanical trauma, accompanying neointimal hyperplasia, risk of stenosis and impaired access survival. (397) Surveillance guidelines should consider differences in risk of thrombosis. For example, newly constructed grafts have a higher risk for thrombosis than established grafts.(396)

Qa and VP surveillance might improve outcomes if measurements are taken more frequently neutralizing hemodynamic variation. Using trend analysis to guide referral decisions rather than relying on a single measurement could be more efficient.

Thus, the screening test should take into account the risks associated with each patient, such as graft age or previous thrombosis, and should not be based solely upon a single Qa measurement.

A systematic review and meta-analysis of available randomized controlled trials evaluated Qa or DUS in AVFs and AFGs. (129) Flow surveillance of AVFs was associated with a significantly reduced relative risk of thrombosis, but no significant improvement in AVF survival. By contrast, there was no evidence that AVG surveillance by flow or DUS reduced thrombosis or improved AVG survival.(129)

Another systemic review and meta-analysis found that serial surveillance of asymptomatic AV access for detection and treatment of stenosis may reduce the risk of thrombosis and prolong VA survival more than usual clinical monitoring but these improvements were not statistically significant.(368)

The frustrating outcome of VA surveillance led researchers to suggest that the current surveillance paradigm might be false and that perhaps we should be looking for a new paradigm.(398)

Modified recommendations were suggested for using Qa and VP measurements in access maintenance emphasizing the importance of physical examination and clinical assessment. (399) Qa or VP measurements should be correlated with physical and clinical examination but are not appropriate as the sole basis for intervention referrals. AVF Qa <400–500 ml/min and AVG Qa <600 ml/min are associated with stenosis, but should be confirmed and correlated with clinical findings when making an intervention referral. The decrease in Qa should be >33% since smaller decreases might be caused by haemodynamic variation.(400) Trend analysis is essential to using static VP/MAP to detect a significant stenosis. The traditional threshold should not be the only basis for an intervention referral.(401)

6.4.3.1.3. Dialysis efficiency measurements

6.4.3.1.3.1. Recirculation

Access recirculation results from the admixture of dialyzed blood with arterial access blood without equilibration with the systemic arterial circulation of dialyzed and non-dialyzed blood. AVF recirculation has two components, VA recirculation that may occur when the blood pump flow is greater than access flow and cardiopulmonary recirculation that results from the return of dialyzed blood without full equilibration with all systemic venous return such as in patients with cardiac disease.

Even with ideal sample timing and proper cannulation, laboratory variability in urea-based measurement methods will produce variability in calculated recirculation.(402, 403) Therefore, individual recirculation values less than 10% by using urea based methods may be clinically unimportant. Values greater than 10% by using urea-based recirculation measurement methods require investigation.

Recirculation rate and access function are closely correlated and it can be assumed that improvements in recirculation rate and HD efficiency are parallel. Thus the use of recirculation rates in evaluation of the indications for and effects of PTA could be expected to contribute to an objective assessment method. The immediate recirculation rate is determined by using the hematocrit dilution technique.(373, 404) The total rate per HD session is reflected by the urea clearance gap. The correlation between Kt/V and immediate recirculation rate is not clear and it may be more appropriate to assess recirculation rate and HD efficiency of the total recirculation.(405)

6.4.3.1.3.2. Urea reduction ratio (URR) and dialysis rate (Kt/V)

The dialysis rate or Kt/V has been suggested as an objective evaluation method for AVF.(406-408) However, it is associated with multiple factors in addition to urea clearance, including the length of HD and quantity of blood flow (QB) which can affect Kt/V values. It is necessary to include the recirculation rate as a factor in functional evaluation of an AVF.(403)

Unexplained decreases in delivered dialysis dose, measured by using Kt/V or URR, are frequently associated with venous outflow stenoses.(409) However, many other factors influence Kt/V and URR, making them less sensitive and less specific for detecting access dysfunction. Inadequate delivery of dialysis dose is more likely to occur with a fistula than a graft.

Failure to detect access dysfunction has consequences on morbidity and mortality.(354, 356, 410) with significant increase in hospitalizations, hospital days and inpatient expenditures. (410)

Thus the diagnosis of inefficient HD by decreased Kt/V or increased recirculation is very important and when accompanied with stenosis. Correction of the stenosis will repair dialysis dose delivery impairment and may improve patient morbidity and mortality.(410)

Recommendation 47

When access blood flow (Qa) measurements during dialysis indicate the presence of a vascular access stenosis, assessment and correction of stenosis should be considered. Class IIa, Level B, Ref.(411)

Recommendation 48

VP/MAP >0.50 (or derived static VP/MAP >0.55) is not a reliable indicator of stenosis and intervention based on this finding is not recommended. Class III, Level B Ref. (401)

Recommendation 49

When impairment of hemodialysis efficiency is detected an underlying vascular access stenosis should be investigated and, if confirmed, it may be corrected. Class IIa, Level B, Ref. (354, 356, 408-410)

6.4.3.2. Surveillance outside dialysis sessions

Surveillance outside HD sessions can be performed using DUS, MRI, CTA or DSA.

6.4.3.2.1. Ultrasound

DUS is the main imaging modality for VA surveillance. DUS can enhance the understanding of the physiology and pathology of every VA. DUS has been described in Chapter IV.

6.4.3.2.2. Angiography

Currently, digital subtraction angiography (DSA) is the gold standard for the evaluation of access patency. DSA can be and is used in some centers as a primary surveillance method when clinical monitoring findings indicates access dysfunction or after DUS examination.

6.4.3.2.3. MRA (CE-MRA and NCE-MRA)

CE-MRA has been introduced for the evaluation of failing access fistulas and grafts. But it is not recommended in CKD patients due to gadolinium-induced NSF.(412, 413)

NCE-MRA is an evolving technology that has been proposed to replace CE-MRA while avoiding the risk of NSF. The technology and algorithms are constantly improving but the instruments are as yet expensive and cannot widely be used.(110, 142)

Recommendation 50

Periodic surveillance of arteriovenous fistulas with duplex ultrasound and preemptive balloon angioplasty can be useful to reduce the risk of arteriovenous fistula thrombosis.
Class IIa, Level B, Ref. (129, 368)

Recommendation 51

Periodic surveillance of arteriovenous grafts with duplex ultrasound and preemptive balloon angioplasty is not recommended to prevent thrombosis or improve arteriovenous graft survival. Class III, Level B, Ref. (414),(129, 368)

6.5. Nursing organization

6.5.1. Introduction

In the last decades, it has been recognized that nurses play a pivotal role in VA management(415, 416) and surveillance.(417) Within Europe organization modalities between HD centers vary from country to country.(418, 419)

The increasing age and co-morbidities of renal patients have resulted in more complex VA(420), demanding higher levels of expertise in the VA management. The coordination of clinical care pathways increasingly rely on nurses(421) from the early stages of planning(43, 422, 423) to cannulation and HD itself.(332, 424) Moreover the expansion of home HD(425-427) has increased the need for patient education and communication skills and remote clinical surveillance.(428, 429)

6.5.2. Nursing organization

Nurses comprise the largest group of health care workers and the way in which they organize their work has considerable effects on patient satisfaction, clinical outcomes. There is a consensus that involvement of nurses in clinical management generates considerable benefits.(430-434)

6.5.2.1. Nursing models

Nurses professionally involved in HD care planning and audit improve their experience and accountability which increases self- esteem and maintains enthusiasm.(435) Case management(436), Primary Nursing(437-440) or similar structured working models(441, 442), applied to the HD setting, have proved to have positive impact on clinical outcomes as well as management performance.(443-445)

6.5.2.2. Clinical governance

Clinical Governance is defined as a framework through which health care organizations are accountable for continuous quality improvement by creating an environment in which excellence in clinical care will flourish. Applying this concept to VA management should enhance the quality of care, decrease clinical risks and improve the monitoring of clinical outcomes for HD patients.(446-449)

For this reason, many countries have invested in specialist VA nurses role.(450-452)

6.5.2.3. Vascular access nurse

VA nurse areas of competence:

- Developing and implementing protocols for staff support and patient education
- VA monitoring implementation
- VA data collection and audit
- Infection and adverse outcome monitoring
- Quality control of VA care
- central line insertion upon specific training,

The role and responsibilities of the VA Nurse vary from unit to unit. The responsibilities of the VA nurse are to the pre-dialysis and out patients service, communication with the VA surgeon, coordination of the operation list and the education of patient and staff, but should also lay more emphasis on cannulation. The VA nurse role can be stratified into three levels, referred to as a VA nurse, VA nurse coordinator(80, 453, 454) or VA nurse manager.(455) In larger units the VA nurses work in teams each member having different responsibilities and roles within the team.

In order to provide examples of VA nurse implementation, the following roles could be introduced in a progressive manner:

6.5.2.3.1. Basic role

The first step for a VA management strategy within the HD care team is the appointment of a VA nurse. The VA nurse should be skilled in VA needling and improving patient care. She/he should be willing to attend continuing education activities and should be willing to organize a continuing education program for nurses within the HD service. Data should be collected on fistula/graft rate, adverse events, CVC type, VA infection rate and staff turn-over starting as soon as the VA nurse is appointed and kept thereafter as a continuing audit for quality control. The VA nurse should have a well-defined job description, which allows him/her to have some autonomy, whilst carefully defining the role and relationships with other team members.

6.5.2.3.2. Vascular access nurse coordinator and manager

These represent possible developments of the basic VA nurse role.⁽⁴⁵⁶⁾ A VA nurse coordinator is responsible for building up and coordinating the VA team work, nursing activity and pathways of care, patient preparation and education in all settings relating to VA implementation, communication with the access surgeon, follow up after surgery, organization of the first treatment/cannulation. Other activities are organizing audits, defining protocols for CVC and AVF management. He/she should have a central role in the multidisciplinary care team. This role requires a full time post in large HD units. The VA coordinator as a highly skilled and educated nurse, supporting HD nurses in any difficult cannulation or helping with CVC management queries.

A multidisciplinary approach to VA including a VA nurse coordinator reduces re-hospitalizations and complications such as VA thrombosis.⁽²⁷⁰⁾ This results in extending VA life and reduces the rate of CVC use.^(270, 361)

Large HD services employ VA nurse managers. Their activities are more on the administrative and management side and are responsible for data collection and evaluation.

Recommendation 52

The appointment of one or more vascular access nurse coordinators should be considered to improve patient care in each hemodialysis service. Class IIa, Level C, Ref (361) (453-456)

6.5.2.4. Future developments

The progression of nursing VA competence enhance the need to organize specific post graduate VA nursing education, which could be a specific module within a Nephrology Nurse Post-Basic Education Course or VA Masters Course(457), in conjunction with universities, industries, professional and patients associations

CHAPTER VII

Late vascular access complications

7.1. True and false access aneurysms

Generalized vessel enlargement is a normal finding in autogenous VA due to flow-induced vascular remodeling. Aneurysms are localized dilatations, whereas true VA aneurysms involve all layers of the vessel wall and false aneurysms have a wall defect.(458) AVF aneurysms are frequently caused or accompanied by pre-aneurysm or post-aneurysm stenosis.(459, 460) A hemodynamically significant stenosis will lead to pulsation of the distal vein and reduced or missing thrill proximally and lead to aneurysmal dilatation.(461-464) Segmental aneurysms without a stenosis may be due to repeated needling in the same area. Large aneurysms can be complicated by wall-adherent thrombi producing local signs of aseptic thrombophlebitis, which can mimic cellulites secondary to bacterial superinfection of a thrombus. Rapidly growing aneurysms lead to necrosis of the overlying skin and the risk of spontaneous rupture and bleeding. In contrast to AVFs, AVGs do not dilate but false aneurysms may develop after graft destruction from repeated needling or at the anastomosis.(465)

VA aneurysms have been reported in up to 17% in AVFs and false aneurysms in 7% AVGs.(343) VA aneurysms are easily detected on clinical inspection but DUS allows detection of associated stenoses and wall-adherent thrombi. VA aneurysms with a thin overlying skin, skin erosion or bleeding should be urgently evaluated and treated(459) but aneurysm diameter per se does not correlate to complications.(460)

Cannulation should be avoided in the affected area, especially when this has a thin (often shiny) overlying skin prone to infection, which is a sign of impending perforation. In cases of progression of aneurysm and stenosis, surgery with partial resection of the wall of the aneurysm (aneurysmorrhaphy) and insertion of the resected material as patch along the

concomitant stenosis is common.(459, 460) Stepwise resection of the aneurysm wall and resizing over a Hegar's probe helps to form a suitable conduit for future cannulation. Other procedures include ligation of the aneurysmal section and bypass or graft interposition. Anastomotic venous aneurysms with a post-stenotic lesion are treated by resection of both lesions and graft interposition to the vein distally. AVG pseudoaneurysms are treated by resection and interposition or bypass. The presence of infection requires exclusion of the aneurysmal section and in most cases, complete resection of the graft (see Section VII :2). In all cases where surgery can provide optimal inner diameter while preserving cannulation sites, PTA should be the second choice. Very little literature exists on the results of surgical treatment of aneurysms. In a small series of 44 VA patients aneurysms or pseudoaneurysms developed in 26 AVFs and 16 AVGs.(460), primary patency for AVFs was 57% at 12 months and 32% after 48 months.(460) AVFs also fared better than AVGs.

Different types of covered stents have been used in endovascular treatment of VA aneurysms and remain an option in selected cases.(461, 466-472)

Recommendation 53

Surgical revision of vascular access aneurysms is recommended if cannulation sites and access diameter can be preserved. Class I, Level C, Ref. (460, 464)

Recommendation 54

Surgical revision of pseudoaneurysms in arteriovenous grafts is recommended when the aneurysm:

- limits the availability of cannulation sites or
- is associated with pain, poor scar formation, spontaneous bleeding and rapid expansion.

Class I, Level B, Ref.(465, 473)

Recommendation 55

Stent graft exclusion of vascular access aneurysms can be considered in selected patients. Class IIb, Level B, Ref. (462, 473-475)

Recommendation 56

Access cannulation through a pseudoaneurysm is not recommended. Class III, Level B, Ref. (132, 133, 135, 459, 460)

Recommendation 57

Outflow stenosis should be ruled out in symptomatic vascular access aneurysms and treated when present. Class I, Level B, Ref. (462, 464, 474, 475)

7.2. Infection

VA infection is the major type of infection in HD patients and the second most frequent cause of death in these patients, only surpassed by cardiovascular disease.(459, 476, 477) Uremia, diabetes, multiple comorbidities, CVCs and repeated cannulation of the VA are important risk factors.(252) Infections occur most commonly in association with CVCs, followed by AVGs and rarely in AVFs.(252) Diagnosis is clinical with local signs such as redness, warmth, tenderness, swelling and purulent discharge or skin erosions or ulcers. However, occult infections do occur with fever as the only symptom. DUS may be used to look for perigraft fluids and radiolabeled leucocyte scans are both sensitive and specific. Non-used accesses may pose an infectious risk and often not apparent clinically.(128, 252, 478)

Infections are caused predominantly by gram-positive cocci (*Staphylococcus aureus* 50-90%, *S epidermis*, *Streptococcus viridans*, *Streptococcus fecalis*.(477, 479, 480) Gram-negative

organisms are found in about 33% of infections.(477, 479-481) Total excision is suggested for grafts infected with *S aureus*, while *S epidermidis* is less virulent and subtotal or partial excision can be planned (252). Infection in methicillin-resistant *S aureus* (MRSA) in 2 studies was associated with higher mortality compared to methicillin-susceptible strains of *S aureus* in HD patients.(482, 483) However, no causal relationship between MRSA and VA infections has been established.(477) AVG infections have been shown to be higher in HIV positive patients (30%) compared to HIV negative (7%) patients. However, no significant increase in VA related infections have been observed in HIV positive patients with AVFs and irrespective of CD4+ counts.(484, 485) Due to their immune-incompetence, AVGs should therefore be avoided in HIV patients.

Late infections are more frequent (50%) and associated with routine HD.(155, 252)

In AVFs, rare infections at the AV anastomosis require immediate surgery with resection of the infected tissue. More often, infections in AVFs occur at cannulation sites, especially in button-hole cannulation with insufficient aseptic technique. Treatment consists of avoiding cannulation at that site. In all cases of AVF infection, antibiotic therapy is begun empirically with broad-spectrum antibiotics and then narrowed down based on culture results. Infections of primary AVFs should be treated for a total of 6 weeks, analogous to subacute bacterial endocarditis, however, proper evidence is lacking.(459)

AVG infection is associated with risk for sepsis and suture-line disruptions with life-threatening bleeding. (252) In general, extensive perigraft effusion requires complete graft removal while in some late infections, unaffected ingrown graft segments can be saved.(252, 486) Late AVG infection may be caused by transient bacteremia from a distant site such as an infected oral cavity. Antibiotic treatment alone is rarely sufficient and may instead require a combination of antibiotics and graft excision. Total graft excision is the most effective way to eradicate infection but usually necessitates placement of a CVC and is associated with a significant amount of tissue destruction when removing established infected grafts.(252, 486) (487). Subtotal excision refers to removal of the graft leaving only a small stump on the

arterial side to be closed. This approach avoids extensive dissection of the artery and risk for nerve damage. If the infection is localized to a segment of the graft and ultrasound shows no perigraft fluid along the rest of the graft, partial excision of the graft can be performed (470) and temporary CVCs avoided.

Outcomes regarding infection are best with total graft removal (1.6% recurrence rate), less in subtotal excision (19%) and 29% in after partial excision.(252, 488-492) The literature diverges on the efficacy of conservative treatment (only antibiotics) and the reason may be that some of the patients do not have a manifest infection but simply a reaction to the prosthetic material that spontaneously resolves and erroneously interpreted as an infection. Lately, reports of conservative treatment of infected AVGs with antibiotics, aggressive debridement and vacuum assisted closure have emerged but the experience is far too scarce to justify any recommendations.(493)

Recommendation 58

All vascular access infections should be treated with antibiotics to cover gram-positive and gram-negative organisms. Further therapy should be guided by culture results. Class I, Level B, Ref. (252, 459, 486)

Recommendation 59

Total arteriovenous graft excision is recommended in patients with sepsis, clinical signs of infection, and perigraft fluid around the whole graft. Class I, Level C, Ref. (252, 486)

Recommendation 60

Partial excision of an arteriovenous prosthetic graft may be considered in select cases when sections of the graft are well incorporated and appear to be uninfected.. Class IIb, Level C, Ref. (470, 489)

7.3. Stenosis and recurrent stenosis

Stenosis can occur at any level from the arterial inflow to the venous outflow, often in the juxta-anastomotic areas or even within the graft.(494) Pre-emptive treatment of all stenoses has not been shown to be of benefit.(317, 495-498) Therefore only stenosis that do have a hemodynamic effect ($\geq 70\%$ decrease in lumen area) and associated with decreased flow, elevated venous pressures, or an abnormal physical exam (less thrill or pulsatile flow) should be treated. The main benefit of preemptive treatment of hemodynamically significant stenoses is decreased thrombosis, avoidance of sub-optimal HD and CVCs, and not necessarily prolonged life of the access.(495, 497-499)

7.3.1. Inflow arterial stenosis

Stenoses in the brachial, radial or ulnar artery are more frequent in elderly, in diabetes and in hypertension. In addition, stenoses often develop at the arteriovenous or arteriograf junction. In a prospective multicenter study it could be demonstrated that about 30% of referrals for stenosis intervention were due to either stenosis in the native artery or at the anastomosis site.(499) In another study 12.5% of dysfunctional AVFs and AVGs were due to inflow stenosis and in 77% endovascular treatment was successful.(500)

PTA is a safe and effective technique with a low rate of reintervention.(499) In case of elastic recoil, rapidly recurrent stenosis, or residual stenosis $>30\%$ after PTA the implantation of a stent is recommended.(459) Open options for treatment of stenoses in the native arteries include bypass and endarterectomy but are seldom performed. No randomized studies have been performed between open and endovascular surgery.

7.3.2. Juxta-anastomotic stenosis

For hemodynamic reasons, stenosis often develops in the juxta-anastomotic area around either the arteriovenous or arterio-graft anastomosis and the first few centimeters (2-5 cm)

into the vein/graft.(494)

Traditionally open surgery with creation of a new proximal anastomosis or interposition with a short ePTFE graft, has been the preferred method in forearm AVFs, (501) although PTA is an alternative.(502, 503) It has been demonstrated that PTA can be used as the primary approach for juxta-anastomotic stenosis.(504) However recurrent stenosis rate is higher than after surgery and in those patients where early recurrence occurs, a surgical revision is indicated. If surgical revision is expected to shorten the usable length of the AVF for cannulation PTA is justified as the primary tool.

7.3.3. Venous outflow stenosis

Reduced VA flow, long bleeding times and elevated venous pressure suggests the presence of a venous outflow stenosis often where the peripheral vein enters the deeper system. PTA is the first treatment option in the outflow veins (cephalic/basilic), especially when the lesion is short (<2 cm). For long-segment stenoses (>2cm), treatment is controversial, including PTA or surgery either by graft interposition or vein transposition. Grafts should be reserved for patients with exhausted peripheral veins whilst fistula preserving procedures such as PTA or patch angioplasty should be favored over graft extensions to central venous segments.

Venous outflow stenoses may be resistant to PTA and require high-pressure balloons or cutting balloons.(505) Stents should be considered if repeated PTA fail. Clinical trials comparing stenting versus PTA did not show statistical significant differences in patency. (506) (507) (508) Stents used in previous RCTs may have been inferior to more recent used devices especially when nitinol stents were used.(509-511) The use of covered stent to treat AV access stenosis has recently gained consensus since they may decrease the incidence of restenosis by interposing an inert layer to separate the thrombogenic vascular wall from the blood flow and impede the migration of smooth muscle cells.(512) Covered stents mimic open surgical revision of a graft, preventing elastic recoil and avoiding trans-stent growth of neointimal tissue. Recently, a multicenter, randomized, controlled trial found better patency

rates for covered stents vs. simple PTA for the treatment of stenosis at the venous graft anastomosis(513) with 51% primary patency at 6 months for covered stents compared to 23% for PTA($P < 0.001$). However, thrombosis was not prevented in the covered stent group and although not statistically significant, the rate of access thrombosis was higher in this group (covered stents 33% vs. PTA 21%; $p < 0.10$). Moreover, the 6 months primary assisted and secondary patency were not statistically different between the two.(513) Concerns remain about costs, and on the real value in preventing graft thrombosis.(514) Thus the use of covered stents to treat AVG venous anastomosis stenosis is reserved for complicated cases. The consensus is that for stenting venous anastomosis and venous stenosis, covered stents may be superior to bare stents.

7.3.4. Cephalic arch stenosis

The cephalic vein forms part of the outflow for RCAVF and is the sole outflow for BCAVF. The cephalic arch is prone to the development of hemodynamically significant stenosis (494, 509)related to the perpendicular junction to the deeper veins. Stenosis in this region is common and is usually treated with PTA.(494) The cephalic arch is the most frequent location for stenosis of upper arm dysfunctional AVFs, comprising 30% to 55% of all upper arm access stenosis sites.(515) It responds poorly to PTA, with a 6-month primary patency rate of 42% (459), which is below the 50% unassisted patency rate recommended for intervention after access stenosis. When the result of PTA is poor or caused vein rupture, or if there was early restenosis (<3months), covered stents can be used. (515, 516) Because of the problem of restenosis after stenting in the cephalic arch, covered stents have been suggested as an alternative in early recurrent cephalic arch stenosis after PTA.^{545, 546}, (517)

A randomized clinical study on the outcome of 25 consecutive patients with recurrent cephalic arch stenosis has shown the following:(517) Angiography at 3 months demonstrated restenosis rates of 70% in the bare stent group and only 18% in the covered stent group. Life-table analysis at 3 and 6 months showed that primary patency was 82% in the covered

stent group and 39% in the bare stent group. One-year primary patency was 32% in the covered stent group and 0% in the bare stent group. It was concluded that the use of covered stents for recurrent cephalic arch stenosis significantly improved short-term restenosis rates and long-term patency compared with the use of bare stents. The major drawback of covered stents in the cephalic arch is possible occlusion of the axillary vein that may prevent further access in the ipsilateral arm, but the rate of this complication is unknown. Therefore, until long term results are published the use of stentgrafts can only be recommended when it is considered unavoidable by an endovascular specialist. The role of DEBs is currently being examined and may offer an alternative to stents in VA.(518, 519) Since the outflow anastomosis can be considered as an experimental model for intimal hyperplasia, future research direction may clarify whether DEBs may offer an alternative to stents in VA.

As an alternative to endovascular therapy, open surgical revision for cephalic arch stenosis has been described and involves diverting the blood flow to other patent veins for example the axillary vein with a primary patency of 60% at 1 year.(520-522) However, such procedures might jeopardize the creation of a future basilic vein fistula. Furthermore, it has been shown that previous endovascular treatment of the cephalic arch decreases the patency of open surgical revision.(523)

Recommendation 61

Balloon angioplasty is recommended as primary treatment for inflow arterial stenosis of any vascular access. Class I, Level B, Ref. (499, 500)

Recommendation 62

Surgical proximal relocation of the vascular access anastomosis is recommended in juxta-anastomotic stenosis in the forearm. Class I, Level B, Ref. (501)

Recommendation 63

Balloon angioplasty is recommended for the treatment of venous outflow stenosis. Class I, Level C, Ref. (508)

Recommendation 64

Balloon angioplasty should be considered for the treatment of cephalic arch stenosis. Class IIa, Level B, Ref. (517)

7.4. Thrombosis

Thrombosis often presents as the final complication after a period of VA dysfunction and is mainly due to progressive stenosis in the access or in the outflow. Treatment needs to be started as soon as possible to prevent organization of the thrombus and prevents endothelial damage in the vein. Early thrombus removal allows immediate use without the need for a CVC.

7.4.1. Treatment of arteriovenous fistula thrombosis

In AVFs, thrombosis usually begins at a stenosis site or needle site and propagates until a side branch that is open. For example in RCAVFs, open side branches drain the cephalic vein even when the anastomosis is thrombosed. However in a transposed basilic vein fistula with no side branches, the entire vein is thrombosed. Early thrombus removal is more urgent in AVFs compared to AVGs because of endothelial damage and phlebitis may preclude further use of the access. Furthermore, the thrombus organization is more pronounced in native vessels.(524) The duration and site of AVF thrombosis as well as the type of access are important determinants of treatment outcome. Originally the management was exclusively surgical thrombectomy. Later, in the 1980s percutaneous management has been proposed by thrombolysis first, in combination with mechanical thrombectomy later. A review

of comparative and noncomparative studies of percutaneous thrombectomy vs. surgical thrombectomy for treatment of AVF thrombosis reveals conflicting results and no definitive preference. In a systematic literature review in 2009 36 studies on endovascular and surgical intervention for thrombosis of AVFs were identified.(525) To date, no randomized studies comparing the 2 alternatives have been published. In forearm fistulas, thrombectomy plus simple reanastomosis of the vein to the artery proximally had a better 1year secondary patency rate of 70-90%, compared to 44-89% after endovascular therapy.(525)

Thrombolysis or thrombectomy alone are not sufficient to restore long-term patency, since a flow-limiting stenosis is present in more than 85%of the cases.(526) Identification and treatment of these underlying lesions are crucial to optimize long term result. The combination of thrombolysis with PTA allows a good immediate result ranging from 88 to 99%, but re-occlusion is frequent.

Endovascular technique includes pharmacological thrombolysis (urokinase or tissue plasminogen activator), pharmaco-mechanical thrombectomy (lytic agent combined with mechanical thrombus maceration), mechanical thrombectomy (thrombosuction, hydrodynamic catheter or catheter with a rotational tool) or a combination of these.(527-529) Pharmacological thrombolysis can result in adequate thrombus resolution but it is time consuming and associated with a higher risk of bleeding and incidence of pulmonary embolization in comparison to surgery. Mechanical thrombectomy devices significantly reduce procedure time. Independently from the type of device used for pharmaco-mechanical or mechanical thrombectomy, the technical success rates are better in AVGs compared to AVFs (99 vs 93%), although early re-thrombosis is more common in AVG.(530) A direct comparison among three different mechanical devices for endovascular recanalization of AV access thrombosis revealed that the result of PTA in the treatment of underlying stenoses was the only predictive value for graft patency.(531)

7.4.2. Treatment of arteriovenous graft thrombosis

Unlike AVF thrombosis, treatment of AVG thrombosis is not as urgent but should be managed without jeopardizing access function for the next HD session. Early declotting allows for immediate use of the access without the need for a CVC. Old thrombi (> 5 days) are often fixed to the vessel wall beyond the venous anastomosis, making surgical extraction more difficult than interventional treatment. Surgical thrombectomy is performed with a thrombectomy catheter purposely designed for use in grafts. Intra- operative angiography can visualize the central venous outflow as well as the graft in order to exclude residual thrombi and identify and treat the cause of thrombosis which should be an integral part of any surgical or interventional declotting procedure.

In a meta-analysis(261) and in a systematic review in 2009(525) the conclusion was that surgical thrombectomy was superior to endovascular therapy. A recent randomized study did not show any significant difference between surgical thrombectomy and endovascular treatment. (532)

Recommendation 65

Thrombosed vascular access should be treated as soon as possible to restore access function for hemodialysis. Class I, Level B, Ref. (525)

Recommendation 66

Late thrombosis of vascular accesses can be treated either by surgery or by endovascular means depending on the center's expertise. Class IIa, Level B, Ref. (525)

Recommendation 67

Treatment of vascular access thrombosis should include perioperative diagnosis and treatment of any associated stenosis. Class I, Level C, Ref. (526, 530, 531)

7.5. Central venous occlusive disease

Central venous occlusive disease (CVOD) is a common finding with an incidence of 2-40%.^(143, 496, 533-535) It may be asymptomatic but can cause upper extremity, facial or breast swelling, increased venous outflow resistance, post-cannulation bleeding, fistula aneurysms, and may lead to loss of the access, and preclude future VA creation in the ipsilateral limb.^(143, 533) These lesions associated with prior CVC use, increased blood flow and by extrinsic compression (see 7.5.1.).^(143, 535, 536) Twelve to thirteen percent of patients with HD access have symptomatic CVOD that may require some form of intervention and 25-50% of all subclavian CVCs are associated with subsequent CVOD whereas lower rates have been reported for jugular vein catheters.^(534, 537, 538) Clinical suspicion of the diagnosis should be confirmed by either fistulography or CTA. DUS is generally less useful since visualization of central venous outflow may be difficult but can be of help using defined criteria.^(539, 540)

There is no ideal treatment for this problem. Since surgery requires sufficient expertise and is associated with increased morbidity PTA with its low morbidity and good short term patency has become the accepted treatment for symptomatic CVOD ⁽⁴⁵⁹⁾. Poor long-term patency rates after PTA are due to elastic recoil ⁽⁵⁴¹⁾ or recurrent intimal hyperplasia and repeated interventions are often necessary. Bare metal stents have not demonstrated an advantage in long-term patency over PTA and are not recommended in mobile axillary vein segments and subclavian segments underneath the clavicle.^(535, 536, 542, 543)

In view of the reported superiority of covered stents compared with bare stents for recurrent cephalic arch stenosis these have been used for cases of symptomatic CVOD ^(517, 544, 545), however the possible disadvantage of covering major venous confluences must be considered.^(546, 547)

Despite a significant morbidity, surgical revision should be considered in patients with CVOD and failed endovascular attempts.⁽⁵⁴⁸⁻⁵⁵¹⁾ Various procedures include bypassing the

central occlusion (axillary or brachial vein to jugular vein; axillary vein to saphenous or iliac veins), intrathoracic central venous reconstructions, extra-anatomical venous reconstruction, and non-venous HD access (axillary or brachial artery to right atrium bypass). Hybrid procedures combining surgical bypass and endovascular recanalization with covered stents may also be an option. In addition, high flow fistulas with CVOD may also be treated with flow reducing procedures such as fistula vein banding.(552, 553)

7.5.1. Hemodialysis-associated venous thoracic outlet syndrome

About 10% of central stenosis occurs without previous CVC placement.(554) Extrinsic compression of the subclavian vein at the costoclavicular junction is a less common cause of venous hypertension or upper extremity swelling in the VA patient, but should be kept in mind, when no CVC has been used. The etiology can be compression of the subclavian vein between the clavicle, first rib and costoclavicular ligament causing thickening of the vein wall, stenosis and thrombosis.(555) Lesions may be asymptomatic until placement of a VA, which increased blood flow, arm swelling and/or cannulation problems.

Diagnosis is obtained by dynamic phlebography with abduction or elevation of the arm. DUS may detect subclavian vein compression before VA placement but the vein segment behind the clavicle is difficult to visualize.(539)

Stenoses with this etiology responds poorly to PTA and stents invariably fail.(556) The treatment of choice is surgical decompression of the thoracic inlet by first rib resection and venolysis.(557) Residual stenosis may require PTA after decompression. Stent placement should be avoided. The largest series of patients treated this way, consisted of 12 patients, 8 of whom achieved patency beyond 8 months.(557) Occlusion of the subclavian vein usually require other treatment strategies such as jugular vein turndown (558), extraanatomical bypass from the axillary vein to the internal jugular vein (559) or decompression followed by subclavian interposition graft (557).

Recommendation 68

Persistent arm edema or development of vein collaterals over the ipsilateral chest region more than 2 weeks after creation of a vascular access should be evaluated by fistulography-or computed tomographic angiography to evaluate ipsilateral central venous outflow. Class I, Level B, Ref. (539, 540)

Recommendation 69

Symptomatic central venous outflow disease should be treated primarily by balloon angioplasty, and repeated interventions when necessary. Class I, Level C, Ref. (535, 536, 542, 543)

Recommendation 70

The use of bare stents is not recommended in the treatment of central vein stenosis. Class III, Level C, Ref. (517, 544, 545)

Recommendation 71

Covered stents or repeat balloon angioplasty may be considered if there is significant elastic recoil of the vein after balloon angioplasty or if recurrent stenosis occurs within less than 3-months. Class IIb, Level B, Ref. (542, 543, 545)

7.6. Vascular access induced limb ischemia and high-flow vascular access

VA induced limb ischemia, often referred to as hand ischemia or 'steal' after primary VA, occurs in 5-10% of cases when the brachial artery is used for inflow but in less than 1% of RCAVFs. Increase in age and diabetes in the HD population has raised the incidence of

symptomatic peripheral ischemia to the hand.(560) Other causes of access associated complications in the lower arm, hand and fingers such as carpal tunnel syndrome, venous hypertension and IMN should be considered when clinical symptoms of ischemia are less pronounced.(561) Regular monitoring after access placement is mandatory and high-risk patients should be carefully evaluated such as elderly and diabetic patients. Clinical examination should include pulse palpation, presence of supraclavicular bruits indicating proximal arterial stenosis, bilateral blood pressure measurements, and evaluation of the hand circulation with and without temporary access occlusion by digital compression.(560) Diagnosis can be obtained by DUS to evaluate distal arm and hand circulation and digital blood pressure measurement or digital pulse oximetry, preferably with and without temporary access occlusion. Surgical or endovascular procedures require information from DSA or CTA.(560, 561) An access surgeon should readily evaluate patients with symptoms of VA-induced ischemia. Non-healing ulcers and emerging digital necrosis should lead to prompt intervention and if limb viability is threatened, access ligation may be the only option. In cases with milder ischemia, symptoms during exercise or HD or rest pain, the cause of the ischemia should be diagnosed and therapy aimed to reduce distal ischemia with maintained access function. Flow reducing arterial stenoses proximal to the anastomosis should be treated with PTA.(562) High-flow–induced steal with VA-induced ischemia requires reduction of outflow diameter to create a significant stenosis (80%) either through banding (563) or by a surgical revision to decrease anastomosis diameter or through the creation of a new AV anastomosis in the forearm arteries as opposed to the brachial artery (RUDI) (Fig 6a-b).(564-566) The procedures should include intraoperative flow monitoring to ensure adequate flow reduction. (567) In RCAVFs with high-flow, ligation of the proximal (or distal) limb of the artery, depending on the cause of the elevated flow may be successful (Fig 6c).(179, 180, 565, 568) VA-induced ischemia with normal or near normal access flow and significant distal vascular disease represent the majority of cases.(255) Several reports support the use of a DRIL procedure.(569-572) Here, the AV anastomosis is bridged by a venous bypass and the artery ligated distal to the AV anastomosis (Fig 6d). The proximal by-pass anastomosis

should be placed at least 10 cm above the access anastomosis to ensure adequate deviation of sufficient flow to the distal extremity. In RCAVFs with ischemia, ligation of the distal limb of the radial artery may be an alternative (Fig 6e). Intraoperative flow monitoring or DUS may be advisable to verify increase in peripheral arterial perfusion.(567, 570) Alternatively, improved distal perfusion may also be obtained by a more proximal AV anastomosis (PAVA) (Fig 6 f). (573) HD patients with VA flow > 1500ml/min should be monitored regularly by flow measurements, echocardiography and clinical signs of CHF evaluated. Progression of symptoms, progressive increase in access flow or objective signs of decreased cardiac function should be considered for surgical procedures described above.

Recommendation 72

In patients with symptomatic vascular access-induced extremity ischemia with arterial inflow stenosis balloon angioplasty should be considered. Class IIa, Level C, Ref.(560, 562)

Recommendation 73

Symptomatic access induced extremity ischemia in patients with high-flow access should be treated by surgical procedures aimed to reduce access flow under intraoperative flow monitoring to ensure optimal flow reduction with maintained access function and improved distal perfusion. Class I, Level C, Ref. (564, 565)

Recommendation 74

A DRIL procedure should be considered in patients with vascular access induced limb ischemia and upper arm access without high-flow. Class IIa, Level C, Ref. (569-572)

7.7. Neuropathy

Distal nerve function can be acutely impaired after AV access placement in the upper extremity using the brachial artery as inflow site. The most serious condition, ischemic

monomelic neuropathy (IMN), is caused by axonal ischemia in peripheral nerves that can lead to severe and nonreversible limb dysfunctions.(561, 574-576) Other causes are aggravation of pre-existing uremic or diabetic neuropathy or nerve compression due to postoperative soft tissue edema.(577) Prevalence and incidence numbers are unknown and case reports prevail . True ischemic neuropathy can affect either nerve although the radial nerve seems most susceptible.(578) The underlying etiology appears to be reduced collateral flow in vessels to major nerves in the antecubital fossa, most often after brachio-cephalic AVFs, with subsequent ischemic axonal injury or reversible demyelination injuries.(575, 579) Diagnosis of acute ischemic neuropathy after access creation is difficult. It should be suspected in patients with diabetes and pre-existing neuropathy, distal arterial disease and after creation of upper arm access. The patient generally presents with immediate postoperative sensory or motor loss in the distribution of all or one of the three major peripheral nerves from motor function compromised to cause wrist drop, sensory compromise with paresthesia and numbness or striking pain. Isolated nerve compromise should be suspected to be due to soft tissue nerve compression. The peripheral circulation is usually satisfactory with a warm hand and even with distal pulses. The condition may mimic true VA-induced ischemia, post-operative edema or carpal tunnel syndrome.(561) It should be treated with immediate access closure to prevent further neurological deficit.(575, 580, 581) Despite adequate actions, persistent neurological deficit and extremity malfunction is common.

Recommendation 75

Patients with diabetes or pre-existing neuropathy receiving an upper arm vascular access should be monitored post-operatively for signs of ischemic neuropathy. Class I, Level C, Ref. (576, 581)

Recommendation 76

Acute ischemic neuropathy should be treated with immediate vascular access closure to prevent further neurological deficit. Class I, Level C, Ref. (575, 580, 581)

7.8. Non-used vascular access

There is neither consensus nor clinical evidence in favor of routine closure of a functioning VA following successful kidney transplantation.(582, 583) Reports indicate that most accesses remain patent after kidney transplantation.(584, 585) VA closure may be indicated in high-risk patients with pre-existing CHF, refractory CHF after transplantation, high-flow accesses, other access complications, and for cosmetic reasons.(582, 583) Access ligation has been shown to improve cardiac function in kidney transplant recipients (584), but, there are few studies reporting follow-up of cardiac function in transplant patients (585-587) and improvement of several physiological parameters have been observed both in patients with patent access as well as after access closure (585). Non-used AVGs may become infected over time, which must be considered in all patients with prior synthetic implants. In a series of 20 patients with non-used AVGs who presented with fever or sepsis positive blood cultures were present in 15 of 20 patients and all were positive on indium scans and had pus around the grafts. (128) Interestingly, in the same study 15 of 21 asymptomatic patients with abandoned, thrombosed ePTFE grafts had positive indium scans. Subsequent removal of the AVG in these patients revealed purulence surrounding the graft in 13 of 15 patients. Another study reported that of all graft infections at their center, 23% were in thrombosed grafts. (155)

Recommendation 77

Routine closure of a functioning vascular access after successful kidney transplantation is not recommended. Class III, Level C, Ref. (582, 583)

Recommendation 78

Vascular access closure may be indicated in patients with refractory heart failure after transplantation. Class IIb, Level C, Ref. (582, 583)

CHAPTER VIII

Complex or tertiary hemodialysis access

There is a subgroup of more challenging patients who will require complex tertiary access. The expectations, age and co-morbidities of the HD population are rising as well as the number of years for which people are being sustained on HD. There are also a group of younger patients who become increasingly sensitized with each failed transplant and thus more difficult to re-transplant from both an anatomical as well as immunological perspective. The factors that result in repeated renal allograft failure are also those that challenge the VA surgeon. These factors include hypotension, thrombophilia and absence of vein in continuity with the right atrium. Achieving tertiary VA often requires the access surgeon to be inventive using their understanding of the general principles of fistula formation as well as vascular anatomy to create an access that may be a unique “one-off”.

Recommendation 79

When standard upper limb vascular access sites have been exhausted complex access procedures need to be considered according to the availability of suitable vessels. Class IIa, Level C

8.1. Tertiary vascular access

8.1.1. Suggested classification of types of tertiary vascular access surgery.

The most appropriate tertiary access procedure for an individual patient depends on their available vessels and the experience of the surgeon. These may be divided into three groups of increasing risk and complexity, which should therefore generally be considered in sequence:

Group one - upper limb, chest wall and trans-located autologous vein from the lower limb (see Chapter V).

Group two - lower limb.

Group three - access spanning the diaphragm, and other unusual access procedures including upper and lower limb arterio-arterial loops.

8.1.1.1. Group one – Upper limb, chest wall and trans-located autologous vein from the lower limb

Upper limb VA is preferred because of the increased morbidity when the lower limb is used. When a functioning upper limb access is jeopardized by central venous stenosis or thrombosis venoplasty or recanalization and stenting of a stenosed or occluded outflow vein should be attempted to treat arm swelling and preserve the access. This includes sharp needle recanalization of the outflow vein if experienced radiological support is available.(588) If recanalization using endovascular techniques fails then the next option could be a bypass using a prosthetic conduit onto the ipsilateral axillary/subclavian(589) or jugular vein(590) via an infra-clavicular or low neck incision respectively (Fig 7a). This chest wall surgery uses exposures identical to the ipsilateral axillary artery – vein loop(590, 591) and ipsilateral axillary artery - jugular vein loop (Fig 7b) as well as the cross-over bypass necklace procedures (592, 593) (Fig 7c). Another option for patients with functioning upper limb access compromised by major central stenoses is a prosthetic bypass from the axillary vein to the saphenous, femoral or iliac vein. The surgical exposures spanning the diaphragm are described in section 8.2.1.3.(549) (594). In another series of eight such cases (550), the upper limb access continues to be needled in the arm and the long chest wall conduit serve purely to decompress the arm.

In a report of 49 patients with only one postoperative death and the remainder all continuing to use their upper limb access it was concluded that prosthetic veno-venous bypass is a robust solution for patients with occluded central veins.(595)

8.1.1.1.1. Great saphenous vein and femoral vein translocation

The GSV translocated to the upper arm is commonly believed to have high complication and poor maturation rates although acceptable results were reported in a recent small series²²⁰.

Using FV as a conduit in the upper arm has good patency but suffers from a very high complication rate, specifically, of steal because of the caliber mismatch.(596)

8.1.1.1.2. Access to the right atrium

A recent innovation designed to minimally invasively access the right atrium is the Hemodialysis Reliable Outflow (HeRO) device. This provides a subcutaneous coupler somewhere in the axilla/upper arm or neck which is at the end of a 5 mm nitinol-reinforced silicone catheter that traverses any central venous lesions before entering the right atrium. The Coupler can then be attached to a 6-mm expanded polytetrafluoroethylene graft which in turn may act as the AVG once anastomosed to an inflow or simply be joined to an existing native AVF in order to salvage or maintain it.

Published experience includes two multicenter studies of 164 and 409 cases(228, 597) and a number of trials comparing the device with other tertiary access procedures(598) and tcCVCs,(599) The 12 month primary and secondary patency rates were reported as 11% and 32% respectively. (600) A further series reported figures of 9.1% and 45.5%.(601) It has been used successfully to treat access-induced arm edema. 643 In one study the average number of previous access attempts prior to placement of a HeRO catheter was as few as two and in addition to poor patency rates. There was a high complication rate with a particularly high incidence of steal syndrome (24%, all women). (600)

8.1.1.2. Group Two - Lower limb

Lower limb VA is associated with steal (95) and infection(213)reinforcing the importance of reconsidering suitability for peritoneal dialysis. This group comprises AVF formation using either the great saphenous vein, femoral vein or AVG. Imaging of the lower limb arteries and veins including the ilio-caval veins is important when planning any lower limb VA as well as taking a full vascular history and measuring the ABI to avoid operating on a patient with PAD.

Some authors have described lower limb access being created preferentially as a result of patient choice. Reasons given include the facilitation of two-handed self-cannulation, having both hands free during HD.(602, 603) The increased risk of sepsis and limb threatening ischaemia does not support this practice.

8.1.1.2.1 Great Saphenous Vein

Once significant lower limb vascular disease has been excluded a few patients may be suitable for an autogenous posterior tibial–greater saphenous lower extremity AVF at the ankle although data is limited.(604)

Data for the saphenous vein thigh loop, which was first described in 1969 and where the GSV is anastomosed to the superficial femoral artery is also poor.(37, 605, 606) In a review 48 patients were reported with 56 sapheno-femoral AVFs.(92) A loop configuration was avoided by anastomosing the GSV to the mid/lower SFA. The cumulative (ie secondary) patency was 65-70% at one year with 5 patients developing pseudoaneurysms.(607) In a small series of 8 patients with saphenous thigh loops the fistulas had poor flow and the complication rate was high with five haematomas, one thrombosis and two fatal hemorrhages.⁶⁵⁰ These data suggest that the GSV performs poorly as an AVF in the lower limb.

Recommendation 80

The use of great saphenous vein for lower limb vascular access is not recommended due to its high incidence of complications. Class III, Level C, Ref. (37, 92, 607)

The main choice to be made is between Femoral Vein Transposition (FVT) and a Lower Extremity Arteriovenous Graft (LEAVG) bridging the femoral vessels either at groin or thigh level (see chapter V). Any prosthetic material placed into the groin carries a significant risk of infection with rates of between 18%(608) and 37.5%.(213) In as study 22 LEAVGs in 21 patients were compared with 60 HeRO devices in 59 patients.(598) This was an

observational study with more obese patients receiving the HeRO device. There were almost twice as many interventions required per annum to maintain HeRO patency than lower extremity graft patency (2.21 vs 1.17) with no differences in infection rate or mortality at 6 months. Obesity however was considered an indication for FVT (93) which suggests that a future study is warranted to compare the infective complications of FVT with the HeRO device.

8.1.1.3. Group three – Access spanning the diaphragm, other unusual access and prosthetic upper or lower limb arterio-arterial loops.

This small group of patients are subjected to a very disparate and unusual range of operations for which no good evidence base exists. They will by definition be end-stage VA patients.

8.1.1.3.1. Axillo-iliac, axillofemoral and axillopopliteal

Long grafts are described tunneled subcutaneously from the axillary artery to the femoral or iliac vein or from the femoral artery to axillary/subclavian vein (Fig 7d). When deciding which pelvic vessels to use, good quality paired arteries and veins should be preserved to retain technical feasibility for renal transplantation. Bypasses from the axillary artery to the IVC are described(595) and the authors have personal experience of creating a left iliac artery to IVC access (Fig 7e). An axillary artery to popliteal vein prosthetic fistula is an example of a unique and rare access tailored to a specific patient's available vessels.(592, 609)

8.1.1.3.2. Arterial – arterial chest wall and lower limb loops

These fistulae warrant consideration for patients without easily accessible venous drainage to the right atrium, patients with PAOD who would be at risk of steal and also because there is no increase in cardiac demand.

In a series of 34 prosthetic axillo-axillary loops placed in 32 (Fig 7f)(610) eleven patients were obese, as defined by a body mass index of $>30 \text{ kg/m}^2$. The secondary patency rate was 59% at 1 year (median, 18 months) with a one year patient survival of 69%. Infection occurred in 15% patients. The 30 % one year mortality demonstrate that this end stage access group is highly morbid. Another report with 36 loop grafts placed in 34 patients of whom 5 had femoral arterial-arterial leg loops follow up was much longer.(611) Primary and secondary patency at one year was 73% and 96% and at 3 years 54% and 87%, respectively. Occlusion of the lower limb arterio-arterio AVFs required immediate thrombectomy for limb salvage, whereas thrombosis of the upper limb access did not result in limb threatening ischaemia.

Recommendation 81

End stage dialysis access patients can be reasonably considered for arterial – arterial loop grafts as a last resort. The axillary artery – axillary artery chest wall loop should be considered before creating a lower limb arterial - arterial loop graft. Class IIb, Level C, Ref. (610, 611)

There are a number of anecdotal access cases that represent case reports, extreme examples of which include the femoro-renal access graft and access grafts sutured to the right atrium via a thoracotomy(612) or sternotomy. These types of procedure are final attempts to gain access in patients who would otherwise perish. A high peri-operative mortality of this major surgery is therefore expected and experienced.

8.2. Complex central venous catheters

Conventional tunneled catheters are discussed in chapter III (3.3.4). Despite the clear evidence that tcCVCs should be avoided by achieving timely native access, there remain a significant number of patients who require placement of complex high-risk salvage lines such as trans-lumbar, trans-hepatic(260, 613) lines and lines through the parenchyma of a failed renal allograft or the native kidney to access the inferior vena cava.(614) The morbidity and mortality of complex line insertions and their short term benefit would suggest that they should only be used after all other options, including complex grafts and peritoneal dialysis have been ruled out. In this context, peritoneal dialysis catheters can be safely placed under local anaesthesia(615-617), may still be possible after previous abdominal surgery (618) and can be used immediately for low volume exchange.(619)

Recommendation 82

Individuals should not undergo the insertion of a high risk complex hemodialysis line without serious consideration of either the placement of a peritoneal dialysis catheter or a tertiary vascular access. Class III, Level C, Ref. (260, 613, 614, 616, 618)

Chapter IX

GAPS in the Evidence

Robust evidence is still needed in many aspects of the management of VA. Adequate trials are lacking. As a consequence most recommendations have been rated evidence of Level B or C.

Future research directions could be defined:

- Trials on durability of prosthetic grafts and CVCs should be started.
- A registry on post access creation ischemic neuropathy would be of great value.
- Patient specific choices for access should be investigated. Do patients with limited life expectancy benefit from AVG more than from AVF?
- Studies evaluating HD techniques should be undertaken: high vs low flow dialysis, intensive HD
- Cannulation hemodynamics and damages to the access through needling
- Organization of early patient referral and of pre-dialysis care are major subjects for research. A policy of venous preservation should be educated and implemented
- Trials on long-term follow-up and cost/benefit analysis for current available treatment techniques
- Studies on tissue engineered grafts
- Studies on new anastomotic technologies (laser)

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APPENDIX I

RECOMMENDED ADDITIONAL REFERENCES